INTERACTIONS BETWEEN BLACK-TAILED DEER AND INTENSIVE FOREST MANAGEMENT

PROBLEM ANALYSIS

INTEGRATED WILDLIFE INTENSIVE FORESTRY RESEARCH

BC

A cooperative project between the Ministries of Environment and Forests

INTERACTIONS BETWEEN BLACK-TAILED DEER AND INTENSIVE FOREST MANAGEMENT

Problem Analysis

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PREFACE

This problem analysis was requested by the Technical Working Group (TWG) directing the Integrated Wildlife-Intensive Forestry Research (IWIFR) program on Vancouver Island. The rationale for the request originates with the TWG's desire to produce sound, well-organized research relevant to the problems of integrating wildlife and forest management.

The IWIFR program began during 1980 and Phase I is scheduled to run through 1985 with an allocated budget of $1.6 million. Phase II, although not confirmed, is intended to run an additional 5 years. The program goal is to carry out a co-ordinated research program that will provide information needed for the effective integration of forest and wildlife (deer and elk) management on Vancouver Island. To promote participation and information exchanges with public and private interests, the TWG directing the study includes representatives of forest industry and public conservation groups, as well as staff from the two sponsoring ministries and the University of British Columbia. Further information on the IWIFR program is available in annual reports and in progress reports for component studies, available from Research Branch, B.C. Ministry of Forests or Ministry of Environment, Victoria.

This problem analysis deals specifically with the ways that intensive forestry treatments modify the manner in which Columbian black-tailed deer select, use, and respond to various habitats.

The objectives are: to define the problems associated with interactions between deer and intensive forestry; to review present knowledge about the problem and to identify information gaps related to it; to identify research topics; to suggest priorities for research; and to recommend approaches to high priority topics.

Readers are directed to Sections 1 and 2 for a detailed discussion of the rationale and objectives of this problem analysis, and to Section 3 for a description of the methods used to develop it.

All aspects of the general ecology and biology of deer and their response to habitat changes have been considered. Section 4 places the problem in perspective. Section 5 reviews general deer ecology, and introduces the important issues underlying both wildlife and forest management. In Sections 6 and 7 the information needs and research topics

required to help alleviate problems between deer and intensive forest management are identified, and recommendations made in Section 8.

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1 INTRODUCTION

The primary objective for black-tailed deer management on Vancouver Island is to provide a minimum annual harvest of 15 000 ± 5000 deer (B.C. Ministry of Environment 1980). This objective, based on the perceived recreational demand for deer (average annual harvest, 1950-1980), requires that deer numbers be maintained at a population level of 150 000-200 000 deer. Such a requirement has important assumptions regarding the potential carrying capacity of Island watersheds for deer, and, in particular, the impact of forest management on that capacity. Concern surrounding forest management impacts on carrying capacity has been generated primarily from deer population declines of 50-80% subsequent to forest harvesting at some locations on Vancouver Island (Section 5.1.1). A need for increased co-operation and co-ordination between intensive forest management and black-tailed deer management is evident (Section 3).

Forest management is the most important land use activity directly and indirectly affecting deer carrying capacity. Any forestry operation that modifies the timber or the understory vegetation (or both) will also modify the area's ability to produce food and cover, the two key components of habitat (Figure 1). Forest management may indirectly affect other population regulating factors such as predation, competition, and the behavioural ecology of deer.

The objectives of forest management in British Columbia are derived primarily from criteria set out in the Forest Act (B.C. Ministry of Forests 1981). The level of harvest is determined by considering 1) the rate of timber production that may be sustained on the area (i.e., based on the composition of forest and its rate of growth, time to establish a new forest, silvicultural treatments expected, and standard of timber use); 2) the short- and long-term implications of alternate rates of timber harvest; 3) the production capabilities and timber requirements; 4) the economic and social objectives of the Crown; 5) any abnormal infestations or devastations of timber on the area; and 6) constraints due to use of an area for purposes other than timber production.

More specific policy objectives concerning wildlife were made explicit in the coastal logging guidelines (B.C. Ministry of Forests 1972). Provincial forests are to be managed for timber production; forage production and grazing by livestock and wildlife; forest oriented recreation; and water, fisheries, and wildlife resource purposes. The coastal logging guidelines

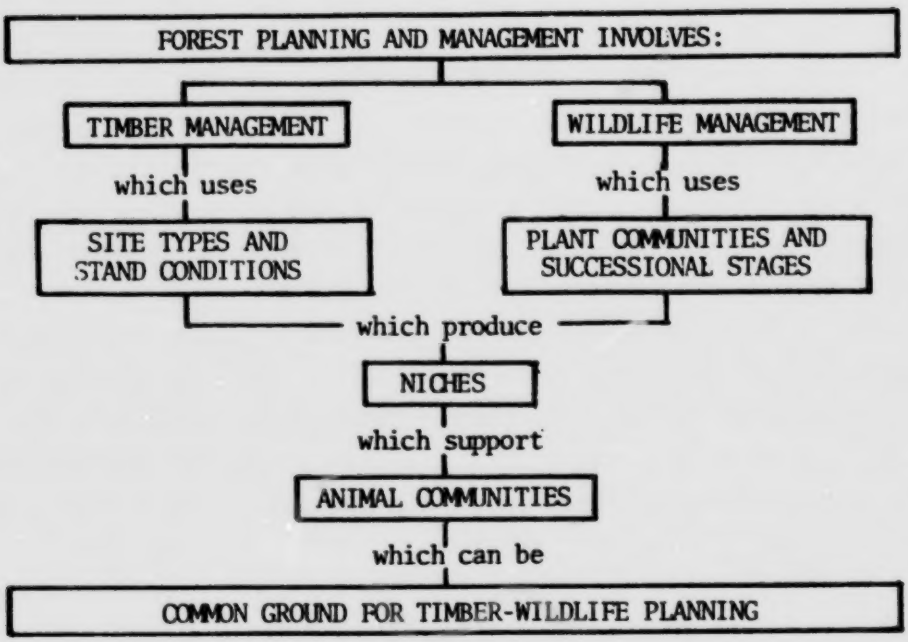

FIGURE 1. Relationship between timber and wildlife (deer) management (from Thomas et al. 1979).

explicitly state a commitment to the multiple use concept of forest management, as well as to the objective of sustained forest yield: "Wildlife and fish habitats of significance are to receive special consideration" (B.C. Ministry of Forests 1972). These forest management objectives come in the light of a radically changing forest management "climate" on Vancouver Island. The forest industry has undergone restraint during the recent economic recession and has had to adapt to a smaller, more unpredictable market place. The nature of supply is also changing. As old-growth, virgin timber is reduced, second-growth forests are comprising the annual allowable cut, which, concurrently, is being decreased. Most of the forest industry depends on intensive silviculture, better use, and conservation of the forest land base to help reduce the deficit caused by the switch from old-growth to second-growth timber.

Intensive silviculture is central to the future nature of forestry, but the best types of treatments and frequency and combination of their use are unclear. This uncertainty stems from changing forestry objectives caused by fluctuating markets and the variety of perspectives held by foresters about which silviculture regimes should be used to meet these objectives (Section 5.3.4). Furthermore, wildlife managers are not able to assess and adequately predict the ecological consequences of site-specific silvicultural practices. With deer, for example, managers are uncertain how forage quantity and quality would be modified, how shelter from predators and climate would be modified, or how an animal's social and reproductive behaviour would change given implementation of certain silvicultural regimes. Without an understanding of this ecological system, the managers are unable to prescribe mutually beneficial harvest patterns with certainty or to judge the effectiveness of alternative management strategies.

This dilemma was the principle force leading to the formation in 1980 of the Integrated Wildlife-Intensive Forestry Research (IWIFR) Program. The goal of this program is to develop and carry out an integrated and co-ordinated forestry-wildlife research program that provides information needed for the effective integration of intensive forest and wildlife management on Vancouver Island. The answer to three major questions are being sought:

1. What are the impacts of intensive silvicultural practices and regimes on wildlife habitat?

2. What are the responses of wildlife to these habitat alterations?
3. How can the information on these impacts and responses be usefully organized?

Three projects are now under way, investigating:

- effects of intensive silviculture on forest vegetation and climate, especially those elements relevant to deer and elk habitat (Nyberg 1985),
- the response of elk to intensive forestry (Janz et al. 1980), and
- the response of deer to intensive forestry (this project).

In addition, there are several smaller projects: an annotated bibliography of deer literature and related documents (Thompson 1981); a preliminary assessment of forestry practices on non-ungulate wildlife (Sadoway, in prep.); an evaluation of LANDSAT imagery to map habitat (Sadoway 1980); an assessment of the potential impact of wolf predation (Hatter 1982); a comparison of ecological classification systems (Stevenson 1982); the development of spatial analysis systems (Scoullar, in prep.); and program design (McNamee et al. 1981).

2 OBJECTIVES

The purpose of this report is to provide a problem analysis for the deer/intensive forestry problem in British Columbia, which can be used to guide research activities for the deer project of the IWIFR program. The analysis has the following specific objectives:

1. To define the problem of deer and intensive forest management relations with respect to deer management objectives, and the perceived impacts of forestry on habitat value, selection, and use by deer (Sections 4-5).
2. To review present knowledge on the problem and identify information gaps related to it (Section 6).
3. To identify research topics (Section 7).
4. To suggest priorities for research (Section 7).
5. To recommend approaches to key topics (Section 8).

Topics approved for study will be treated subsequently in separate working plans that will detail how the research is to be conducted.

3 METHODS

This investigation into the problem of deer and intensive forestry relations was accomplished largely through discussion with professional foresters and biologists, who have been or are currently involved with either of these two resources. The nature of these discussions ranged from individual interviews to group workshops. Many research projects regarding aspects of deer and intensive forestry relations in British Columbia have been in progress since the late 1960's. A review of the historical development of modern era deer research in the province was given by Bunnell (1979). Where possible, information and data from these research projects have been used in this report, and the individual researchers contacted for their perspectives on the problem. Appendix 1 lists the agencies, companies, and individuals interviewed during the initial phases of this document's preparation.

The basic objective in obtaining the professionals' perspectives was to gain a range of ideas concerning the problem definition, its scope, information needs, and potential research directions.

Concurrent with the interviews was the collection of literature pertinent to the problem. Participation in three projects (v. Shank and Bunnell 1982a; Shank and Bunnell 1982b; and Bunnell et al. 1985), as well as participation in the IWIFR technical working group, helped us to focus attention on management and research information needs.

4 PROBLEM SCOPE

The problem between black-tailed deer and intensive forestry activities is primarily a conflict in objectives between agencies concerned with management of these two resources. Forest managers, wildlife managers, and those people concerned with forest-wildlife research neither completely agree nor disagree in their perceptions regarding a solution to the current resource management problem. Most, but not all, agree on the geographic scope and the seriousness of the problem.

4.1 Perceptions Held by Forest Managers

The charge of managing the forest resource of British Columbia rests primarily with the B.C. Ministry of Forests (MOF). Because only 4% of the province's forested land is privately owned, it is assumed that management

efforts reflect the policy of the British Columbia Forest Service (BCFS) either directly, on Crown land, or indirectly, on leased Crown land. General policy information was presented in Section 1.

The general perceptions held by forestry proponents of the conflicts between intensive forestry and black-tailed deer management include the following:

Industry

1. Deer survival decreases with the occurrence of persistent severe winters except in those areas where old growth provides shelter from deep snow. A further decline of current deer populations is inevitable if old-growth forests are removed.
2. There is a lack of understanding concerning how and why deer depend on old growth as winter range.
3. How does intensive forestry modify critical components of winter range, and how can second-growth forests be modified to "mimic" old-growth winter range conditions? How can spring forage be produced?
4. Wolves are an important issue, but one which should have less research priority. If deer habitat research and management are to be justified, wolf management is needed to lower population levels and thus reduce the potential for predation.
5. The geographic scope of the problem exists only in the high snowfall areas of Vancouver Island.
6. The problem is ultimately the responsibility of BCFS, but there appears to be a lack of agreement between industry and BCFS regarding appropriate objectives.
7. The problem affects industry through loss of timber and the creation of difficulties in planning. Historically, constraints have been unanticipated by industry due to lack of "lead time."
8. Historic data on deer trends, forest harvesting, wolf indices, and climate need re-analysis.

British Columbia Forest Service (BCFS).

The BCFS perceives the problem in basically the same way as the forest industry does, with two major exceptions:

1. Wolves are considered more important than spring forage production.
2. The geographic scope of the problem extends throughout Columbian black-tailed deer range from southeast Alaska to the Olympic Peninsula in Washington.

4.2 Perceptions Held by Wildlife Managers

The charge of managing black-tailed deer in British Columbia rests with the Wildlife Branch within the B.C. Ministry of Environment. The policy of this public agency is to manage deer primarily as a game species. The emphasis in management is placed on providing a harvestable surplus in locations of high, or moderate to high, deer production capability and in those locations most accessible to hunters (B.C. Ministry of Environment 1980). The perspectives of the Wildlife Branch that concern interactions between intensive forestry and black-tailed deer are:

1. The present rate of harvesting old growth will prevent the Ministry of Environment from maintaining its objective of providing deer in sufficient abundance to meet the recreational and economic needs of society (see Section 1).
2. Recently, the problem of wolf predation on deer has become more clear as a factor limiting deer populations.
3. Second-growth timber up to 200 years old does not provide the same essential winter range characteristics as does old-growth timber. Silvicultural manipulations of second-growth will likely be uneconomical.
4. Currently there is a lack of research effort into the whole problem of deer management. There is a need to learn how deer cope.
5. Wolf predation has a short-term effect; winter range loss will last for over 200 years and thus is a long-term influence.
6. The problem exists from southeast Alaska to the Olympic Peninsula, but the high snowfall areas on Vancouver Island are the most important locations, representing 50% of the high capability land for deer on the Island.
7. Snow hardness is one of the most important characteristics of snow, but there is no way of managing or controlling this feature.
8. With wolves in the system, security cover deserves more attention than it has received in the past.

9. Manipulation of second growth is a questionable alternative to winter range production because winter ranges are diverse and such diversity would be difficult to simulate.

4.3 Perceptions Held by Academic Researchers

Research concerning declining black-tailed deer populations in British Columbia began in the late 1960's (Bunnell 1979). Studies during the 1970's that address the intensive forestry and black-tailed deer situation were implemented primarily in the Nimpkish Valley on Vancouver Island. In 1980, IWIFR was formed with the objective of initiating co-operative research through the governmental agencies of the B.C. Ministry of Forests and Ministry of Environment.

The following represent generalities of researchers' perspectives concerning the intensive forestry and black-tailed deer management problem:

1. Important issues in the past have been primarily associated with deer population declines, which have been a combination of severe winter concurrent with loss of winter habitat. Now wolf predation is also considered an important factor.
2. A lack of clarity exists concerning the target of various research approaches and their goals.
3. There is a need for more thorough analysis of the Vancouver Island data that has been collected on forest harvesting, climate, deer harvest, and predators with the intent of producing a more balanced approach at studying the problem.
4. The problem is restricted to areas of high snowfall within coastal black-tailed deer range in North America.
5. There is a need to continue collecting baseline data on the overall problem, but research should concentrate on gaining specific information for "process level" understanding.
6. Important focuses for winter range research are:
   i) winter range dynamics (controlled by climate), ii) vegetation and how it is influenced by snowpacks, and iii) snow in winter range.

4.4 Summary: Perspectives and Problem Location

Within the perceptions held by the agencies and forest companies polled, it is evident that historic trends in research have influenced current thinking. All interviewees believe winter range to be an important limiting

factor in deer populations on Vancouver Island. Most believe the problem to exist only in high snowfall areas, and the forest industry alone feels the problem is restricted to Vancouver Island.

In light of recent investigations (e.g., Jones and Mason 1983) most people are expanding their perceptions to include the importance of wolf predation on Vancouver Island deer. Admittedly, most still believe winter range to be the more critical question due to its longer-term influence. The forest industry is most interested in solving the winter range problem so that difficulties with planning and constraints on timber harvest may be minimized.

All people polled agree there is a need for productive research, but few agree on the appropriate research direction. Most agree that the first step is a more strict analysis of baseline data already gathered (Section 7).

In the following sections of this report the problem will be approached from an ecological viewpoint, with the aim of identifying information needs based on ecological principles (Section 5.1). Most attention is on the specific subject of deer response to habitat changes, but because the ecological community is interconnected, some attention will also be on deer habitat responses to forest management activity, and on the potential changing influences of predation and competition due to intensive forestry.

The problem extends throughout black-tailed deer range in British Columbia (Figure 2), which overlaps with two Coastal Biogeoclimatic Zones (Figure 3). Tables 1 and 2 provide details of the biotic and abiotic environments in the forest community within the area where intensive forestry and deer management are a problem.

5 THE PROBLEM DEFINITION

An overview of deer ecology is presented in Section 5.1. Following sections clarify characteristics of the problem between black-tailed deer management (Section 5.2) and forest management (Section 5.3).

5.1 Wildlife Ecology Context

Bunnell (pers. comm., Jan. 15,1984) considered management of a species to be "the application of ecological principles within a particular socio-economic framework". In this analysis we explore the basic ecological principles associated with deer management.

FIGURE 2. Geographic range of (1) Rocky Mountain mule deer, (2) desert mule deer, (2a) Tiburon Island mule deer, (3) California mule deer, (4) Southern mule deer, (4a) Cedros Island mule deer, (5) peninsula mule deer, (6) Columbian black-tailed deer, and (7) Sitka black-tailed deer (from Wallmo 1981).

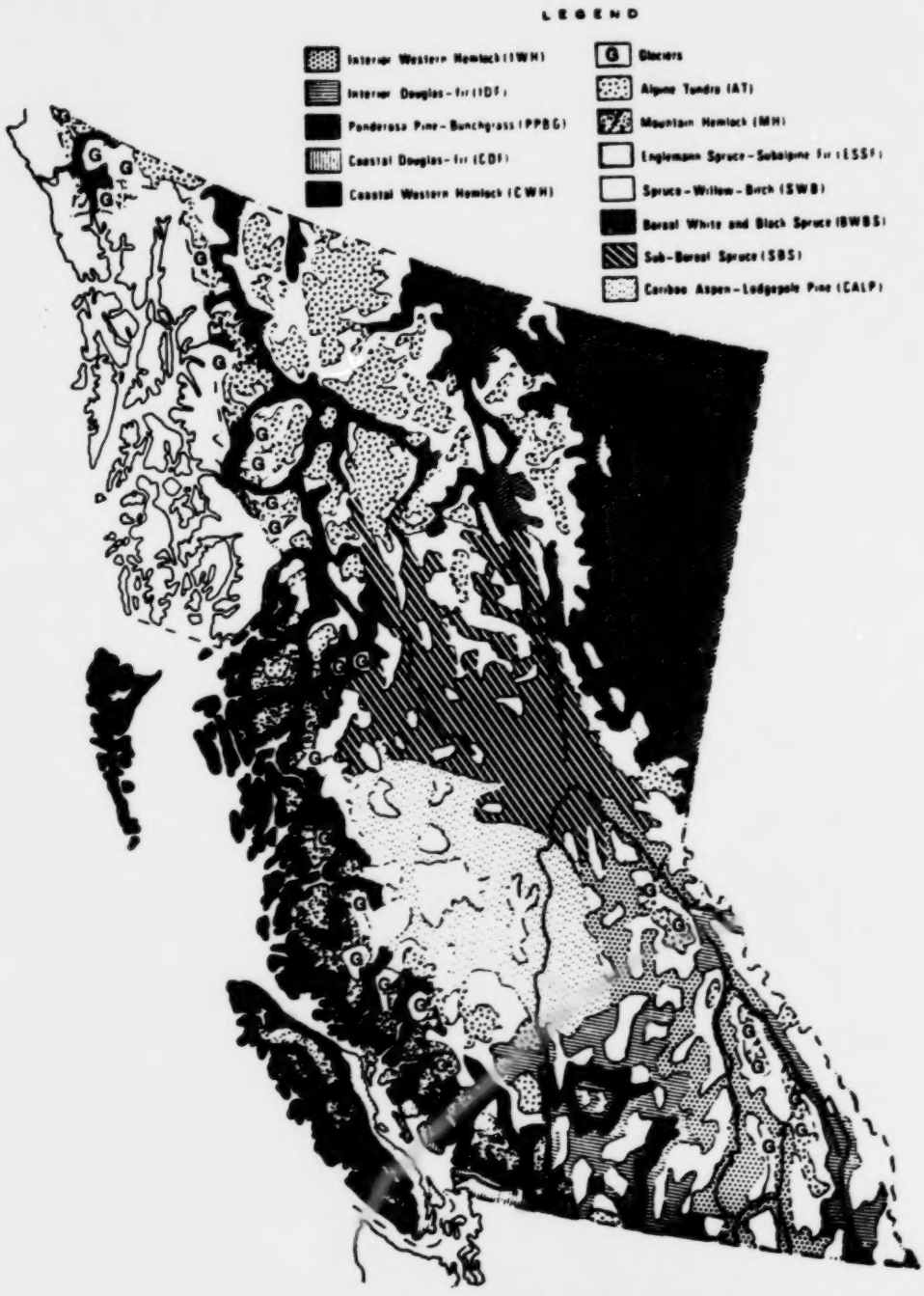

FIGURE 3. Biogeoclimatic zones of British Columbia (from Krajina et al. 1982).

TABLE 1. Biotic features of the Coastal Western Hemlock and Coastal Douglas-fir Biogeoclimatic Zones of British Columbia

Tree species of the coastal forest[1]	Common browse species of black-tailed deer[2]	Conspecific species of the black-tailed deer	Predators of the black-tailed deer
Western Redcedar (Thuja plicata)	Vine Maple (Acer cercinatum)	Elk (Cervus elaphus roosivelti)[3]	Hunters
Western Hemlock (Tsuga heterophylla)	Saskatoon (Amelanchier spp.)	Mountain Goat (Oreamnos americanus)	Wolf (Canis lopus)
Sitka Spruce (Picea sitchensis)	Red Stem Ceonothus (Ceanothus sanguineus)		Cougar (Felis concolor)
Douglas-Fir (Pseudotsuga menziesii)	Red Osier Dogwood (Cornus stolonifer)		Black Bear (Ursus americanus)
Amabilis Fir (Abies amabilis)	Salal (Gaultheria shallon)		Grizzly Bear (Ursus horribilis)
Yellow Cypress (Chamaecyparis nootkatensis)	Ocean Spray (Holodiscus discolor)		Lynx (Lynx rufus)
Mountain Hemlock (Tsuga mertensiana)	Lupines (Lupinus spp.)		Coyote (Canis latrans)
Alpine Fir (Abies lasiocarpa)	Oregon Grape (Berberis spp.)		Dog (Canis familiaris)
Western White Pine (Pinus monticola)	False Azalea (Menziesia ferruginea)		
Black Cottonwood (Populus trichocarpa)	False Box (Pachistima myrsinites)		
Red Alder (Alnus rubra)	Bitter Cherry (Prunus emarginata)		
Bigleaf Maple (Acer macrophyllum)	Douglas-Fir (Pseudotsuga menziesii)		
Arbutus (Arbutus menziesii)	Red Current (Ribes sanguineum)		
Garry Oak (Quercus garryana)	Thimbleberry (Rubus parviflorus)		
	Willow (Salix spp.)		
	Red-berry Elder (Sambucus racemosa)		
	Pacific Yew (Taxus plicata)		
	Huckleberry (Vaccinium spp.)		
	Red Cedar (Thuja plicata)		

[1] From Hosie 1975.
[2] Browse species used to some extent by black-tailed deer (from Forbes 1975 and Rochelle 1980).
[3] Potential overlap during severe winters in north coastal range.

TABLE 2. Abiotic features of the Coastal Western Hemlock and Coastal Douglas-fir Biogeoclimatic Zones of British Columbia

Abiotic feature	Biogeoclimatic zone[1]	
	Coastal Western Hemlock	Coastal Douglas-fir
Number of frost-free days	170 - 344	280 - 354
January mean monthly (°C)	-10 - 5	0 - 4
July mean monthly (°C)	13 - 19	15 - 19
Number of months above 10°C	4 - 7	5 - 6
Number of months under 0°C	0 - 3	0 - 1
Absolute maximum (0°C)	26 - 43	31 - 41
Absolute minimum (0°C)	-45 - -12	-25 - -12
Annual mean total precipitation (mm)	737 - 6655	657 - 1741
Annual mean snowfall (cm)	18 - 792	25 - 162
Elevation (m)	North: 0-300 South: windwardside: 0-900 leewardside: 450-1050	Vancouver Island: 0-450 South coast of mainland: 0-150
Major soils	Humo-Ferric and Ferro Humic Podzols, Gleysols and organic soils	Dystric Brunisols, Humo-Ferric Podzols, Gleysols and organic soils

[1] From Krajina et al. 1982.

5.1.1 Basic requirements from the physical environment

Deer respond to the constraints of the physical environment. Water, cover, energy, and chemical nutrients are the basic requirements for deer. Water is generally plentiful, although body need is affected by environmental factors such as temperature, humidity, forage succulence, and rate of food consumption.

5.1.1.1 Cover

Cover can mean several things to an animal, but generally it is a utility derived from the structure of the terrain and vegetation in which the animal lives. Northern deer use three types of cover: thermal cover, security cover (hiding and escape cover), and cover from deep snow depths in winter.

Thermal cover provides shelter from extremes in temperature and wind (Verme and Ozoga 1971; Beall 1974). A deer loses energy to the environment by convection, radiation, evaporation, and conduction. The rate of energy loss is a function of air temperature, radiant energy environment, and windspeed. Windspeed appears to be the most critical factor (Moen 1968b). Most researchers have attempted to test the effect of temperature and wind on thermoregulatory stress, but only in controlled chamber conditions. Only rarely have effects of these factors been evaluated in natural environmental conditions. Parker and Robbins (1984) found that temperature, wind, and radiation all significantly affect thermoregulation of mule deer, but suggested that these factors should be evaluated relative to broader energy trade-offs before being considered important to management of deer.

Microclimate, as a function of weather, topography, and vegetation, influences a deer's thermal costs. Managers tend to think of thermal cover in terms of site or stand characteristics that provide a thermal-neutral environment for deer during various weather conditions and/or weather changes.

Deer also use cover for resting, hiding, and perhaps escaping from predators and hunters. Thomas et al. (1979) referred to this cover as security cover (see Sections 5.1.2 and 5.1.4). Vegetation or topography may protect deer from predators or other disturbances while they are engaged in normal activities (such as foraging, resting, and reproduction). Peek (1980) suggested that environmental factors are a critical component in

predator-prey systems because environmental attributes are often the ultimate factor involved in predisposing prey to predators.

Cover from deep snow is particularly well documented as an important requirement for deer in eastern North America (Severinghaus 1947; Verme 1965). Edwards (1956) and Jones (1975) documented the need in western Canada. Snow affects ungulates by burying food and altering their efficiency of locomotion (i.e., movement through snow requires a considerable increase in energy expenditure). The latter affects not only the total energy expenditure, but ability to escape from predators as well. Energy expenditure is related to the depth to which animals sink in the snowpack (Heinonen et al. 1959; Ramaswamy et al. 1966; Jacobsen 1973). Actual energy expenditures in relation to snow depth have been measured for some ungulates (Mattfield 1974; Parker et al. 1984), and relationships between species, body measurements, and effects of snow depth on locomotion costs have been developed (Bunnell 1978; Pruitt 1979; Parker et al. 1984). The most recent quantitative report (Parker et al. 1984) indicates that locomotion in snow can increase energy expenditures by 5 times the basic metabolic rate (BMR).

The complexities among forest characteristics (i.e., cover characteristics), snowpack characteristics, and animal energy expenditures has been the subject of many reports (see Shank and Bunnell (1982a, 1982b) for annotations).

Depth, density, and hardness of snowpack appear to be the primary characteristics that determine the effect of snow on ungulates (Nasimovich 1955; Kelsall and Prescott 1971; Telfer 1971; Coady 1974; Bunnell 1978; Harestad and Bunnell 1979). Estimation of energy expenditure allows the evaluation of various deer habitats, in terms of the relative benefits and costs of differing habitat use.

5.1.1.2 Energy and chemical nutrients

Deer are generalist herbivores, which means that their diet is composed of a wide variety of plant species and plant parts (Nyberg 1985). Foods are selected largely by smell but taste and texture are also important (Short 1981). Physiologically, deer are adapted for foraging quickly and digesting the collected foodstuff at a later time. This affords them less chance of being located by predators, and makes the areal concentration of food sources important (Short 1981). Also important are digestibility and rate of

digestion, both influenced by cell structure and chemical composition of forage.

The nutrients required by deer include carbohydrates (cellulose, starches, and simple sugars), lipids, nitrogen, protein, vitamins, and minerals. Cellulose requires a lengthy fermentation time for digestion, whereas starches and sugars require shorter fermentation time and provide a higher energy value. Fats provide the highest caloric value per gram of any foodstuffs selected by deer but require a lengthy fermentation time. Deer are particularly efficient at maintaining the quality of their protein diet by protein synthesis, although the quantity of protein ingested can be a problem. Until the last decade protein levels in deer forage (diets) were often regarded as the limiting factors to animal condition and productivity (Einarsen 1946; Klein 1963, 1965). Deer require 16% protein in their diet and usually have low survival and low natality success with diets of 7% protein or less (Verme and Ullrey 1972). Other reports have indicated that crude protein levels in the 6-7% range are sufficient minimum levels for winter maintenance (Dietz 1965).

Most succulent and immature grasses, forbs, and browse leaves are all easily digested by deer and provide more energy than do diets high in cellulose, including mature grasses and forbs or woody twigs (Short 1981).

Short (1981) considered most vitamins and minerals to be plentiful enough to satisfy black-tailed deer. No history of mineral nor vitamin deficiencies has ever been reported in the Pacific Northwest, although iodine and selenium can present problems. Selenium, for example, can be deficient (causing nutritional muscular dystrophy) or at toxic levels (causing alkali disease). To our knowledge no clear evidence has ever been reported that proves either deficiency or toxicity problems in black-tailed deer.

The quality of food sources in terms of protein, energy, and other nutrient content, and in terms of their digestibility, governs the relative physical availability of food to the deer. In addition, the quality of the food in a deer's diet determines the actual amount of forage the deer can ingest, process, and pass in a certain time interval. Quality affects foraging efficiency or nutrient intake per time per habitat.

Energy and protein levels are usually considered to be the limiting factors of forage quality. Energy is needed to "fuel" the deer, and nitrogen is needed for protein synthesis to build body tissue (Hanley 1981).

Another factor affecting forage quality is the presence of plant secondary compounds such as plant toxins and other digestion-inhibiting compounds. The simplified end result is that actual availability of energy, protein, and other nutrients may be much less than what is indicated by current annual growth or chemical analysis of forage.

5.1.1.3 Temporal and spatial variation

Two other aspects of the physical environment to which deer respond are the temporal and spatial variation of food, cover, and water. We are particularly interested in spatial variation at two levels: 1) local variation caused by geological and topographical features (e.g., how areas of winter habitat and areas of spring forage production are located with respect to one another); and 2) the diversity of environments at a given place, resulting from physical and biological features (e.g., the variation in snow accumulation patterns and forage production within an old-growth forest).

The temporal variations of interest here are exemplified by habitat response to intensive silviculture practices and the timing of those practices (Nyberg 1985). Another example is deer population responses to the timing and extent of predation or hunter harvests.

5.1.2 Predation

The following description of predator-prey systems has been extracted primarily from Hatter (1982). Leopold (1933) and Holling (1959) stated that the effects of predation on prey depend on: 1) density of the prey population, 2) density of predator population, 3) defense or escape capability of the prey, 4) food preferences of predator as well as its ability to detect, capture and kill the prey, and 5) density and quality of alternative foods available to the predator. Within predator-ungulate systems, the predators may: 1) cause prey populations to be unstable and may drive them to extinction; 2) have a regulating effect; or, 3) just reduce rates of population growth. Predators affect prey populations by influencing morphological, physiological, and behavioural responses of prey to predators. Disturbance alters the behaviour of animals and may affect their physiology, population dynamics, and ecology. The unpredictability of a source of disturbance may cause loss of weight, loss of appetite, neurosis, susceptibility to predators, lower reproductive capacity, and even death. Theoretically, any disturbance has the undesirable effect of raising

metabolism and thus the "energy cost of living" (Geist 1971). Some habitat conditions lessen the risk of predation by offering the deer more security.

Connolly (1981) presented 15 case studies of predation on mule and black-tailed deer. The case histories involve predation by coyote, wolf, bear, and cougar. Two important points can be summarized from the review by Connolly (1981):

1. Deer are ultimately limited by quality and quantity of habitat. This means that if deer numbers exist below the level that can be supported by their habitat, then a release from predation could increase population size (Robinette et al. 1977). This is further explained by Messier (1981) as the "predator control" hypothesis. However, declines due to deterioration of habitat quality or quantity cannot be reverted by lowering predator numbers.
2. Two cases presented by Connolly (1981) were able to document predators as the major cause of deer decline. Predators do kill large numbers of deer (Merriam 1964; Knowles 1976) and, under particularly harsh circumstances for deer (such as severe winters), can be a serious limiting factor (Wallmo 1981; Jones and Mason 1983). Messier (1981) refers to this as the "environmental limitation" hypothesis.

5.1.3 Competition

Ricklefs (1973:867) defined competition as "a situation where the use of a resource -- food, water, or cover -- by one individual reduces the availability of that resource to other individuals, whether of same species or a different species". Within an ecosystem or an ecological community, each animal (or plant) becomes part of another's environment, and interactions automatically become part of the total dynamic process of population regulation (Mackie 1981). Within the context of this report, competition can take many direct or indirect forms but most are subtle and difficult to identify. Intra-specific competition is exemplified within deer wintering areas during severe winters. Weaker deer will die of malnutrition or starvation, leaving only the stronger competitors to survive. Less obvious is the indirect interspecific competition between wild ungulates. Gradual reduction in plant vigour, reduction or elimination of particular cover types, and general alteration and reductions in the kind, quality, and quantities of preferred plants have potential to cause severe indirect

competition between and among ungulate species on overlapping ranges (Mackie 1981).

Perhaps the most common and least obvious interspecific competition concerning deer is posed by man. The need for this report demonstrates how little is understood about competition between deer and man for a common resource base -- one which provides a habitat for deer and a potentially profitable resource base for man.

5.1.4 Social/behavioural implications: adaptive strategies

In every aspect of deer ecology one can recognize a strong link with behaviour. The way in which an animal perceives and reacts to its physical environment, its predators, its competitors, and its own species socially and reproductively, determines the animal's survival and transfer of genetic material to new generations. Thus, in an ecological and evolutionary way, animal behaviour is the most proximal tool an animal has to ensure its struggle for survival is successful.

Food habits

Deer exhibit a plasticity of food habits, allowing them to seek the most nutritious species throughout an annual cycle (Rochelle 1980). The physiological processes of deer appear to be adapted to seasonal changes in food availability and quality. Most deer exhibit characteristic annual cycles in metabolic rate, forage intake, body growth, and fat storage-depletion (Bandy et al. 1970).

During summer, deer are more active, their metabolic rate is high, and energy demands for growth and activity are high. At the same time, forage intake and digestibility are high, making the rate of energy and nutrient intake high. Typically, food intake (energy and nutrients) will exceed acquistion costs, and deer will grow and accumulate fat. An early starting and long lasting summer is the most beneficial for deer.

In fall, the basal metabolic rate (BMR) drops, but energy demands are higher due to higher thermoregulation costs and possibly to the increased activity costs associated with negotiating snow. Forage is less digestible and less abundant, and thus forage intake, and consequently energy intake, drop. Typically, except for rutting bucks, energy intake and expenditure are equal and body condition remains stable, relative to other seasons.

Two scenarios are possible during winter. First, in a mild winter with little snow, BMR drops again and deer are less active although thermoregulatory costs are higher. Forage is less abundant and is of much lower quality than in fall. Forage intake drops, thus energy intake drops. Typically, the deer uses its fat reserve over the winter. Second, in a severe winter with much snow, BMR drops still further and deer are less active, but thermoregulation costs and locomotion costs are potentially much higher due to cold temperatures and deep snow. The deer operates at a high energy deficit, depletes its fat reserves within a few weeks, and then starts to catabolize body tissue. If the severe period is too long the deer will die. Typically deer can exist 4-5 weeks without food by staying inactive and still recover, although this may have delayed costs in terms of survival of young born the following spring (DeCalasta et al. 1975)

In spring, the BMR increases. Energy and protein demands for replacement of depleted body reserves, growth, and gestation are high. Such demands require a high increase of forage intake. Forage digestibility and food passage rates are highest at this time allowing for high energy assets.

Regardless of season, however, food habits generally appear so plastic that Geist (1981) stated that a deer's diet is more a function of habitat preference than of forage preference. Moen (1968a) wrote much the same argument when he considered feeding and resting behaviour of deer to be primarily a function of weather. Arguments such as those presented by Geist and Moen lead to the suspicion that deer select habitat based on its cover characteristics or perhaps on their own learned behaviour, and then select forage items within the habitat they have chosen.

Home Range

To a large degree a deer's movements are confined to a limited area known as its home range. Typically, home ranges are defined as annual home ranges or seasonal home ranges, the latter being core areas of seasonal use within the annual home range. For any individual, the home range determines the array of habitat available and likely to be used.

The way in which deer establish their home ranges essentially determines the distribution of deer over the landscape. Home ranges for some deer, especially for females, apparently are learned in the first

year or two of life from association with their mothers (Dasmann and Taber 1956; Nelson and Mech 1981). For other deer, especially young males, home range locations may be established after dispersal. The proportion of "learners" versus "dispersers" in black-tailed deer populations is not known and the process of dispersal is not well understood (Bunnell 1979). From the little work that has been done on this topic, deer appear to disperse randomly (Bunnell and Harestad 1983). Further, for dispersal to have been retained in black-tailed deer populations it must be a relatively successful "life history strategy" with respect to survival and reproductive success.

Home range fidelity and home range size are two parameters of critical importance to the spatial management of both winter and spring range and the understanding of winter and early spring habitat selection. Because fidelity to home range appears to be high, and because quality of habitats is not uniform over the landscape, some deer will fare better than others (Hanley 1981). In fact, some studies have suggested that deer will starve to death on their traditional home ranges rather than move a short distance to areas of more abundant forage (Dasmann and Taber 1956).

Anti-predator strategies

A host of anti-predator strategies for deer have been documented. Deer can respond to predators (hunters included) by changing activity patterns, sociability and wariness, and, most importantly, habitat selection and use. Some behavioural anti-predator strategies (summarized from Hatter 1982) are freezing behaviour; stotting or bounding gait (adapted to broken terrain); herding in open habitats (which lessen vulnerability of an individual deer and confuses the search image of predators); yarding behaviour and "trailing" in wintering areas (to provide multiple escape routes); and modifying daily activity patterns (to minimize predator encounter). Additionally, habitat selection can change as a direct response to the need to hide or escape from a predator, or as a local change in deer distribution to avoid predation. Hoskinson and Mech (1976) documented a migration of deer into areas with high levels of human activity. They proposed that this occurred because the human activity excluded predators from the area. Nelson and Mech (1981) noted that deer set up their home ranges

within the periphery of wolf pack territories, although Messier and Barrette (1985) never observed that behaviour.

Sweeney et al. (1971) put forth the hypothesis that deer restrict their movements to areas of escape terrain. A stotting or bounding gait is used to give deer an advantage in rough terrain during vertical ascents (Eslinger 1976). The stotting gait also allows for unpredictable changes in direction (Geist 1981).

General behaviour

Deer respond to their thermal environment (temperature and/or wind induced) in both a physiological and behavioural manner. Various thermoregulatory responses include: vasoconstriction, piloerection, and actual reduction in heart rate accompanied by a decrease in surface body temperature (lethargy). Further, heat loss can also be reduced by changes in orientation, posture (such as bedding), and reduction in activity. Significant proportions of energy are exerted by both males and females during the fall courtship and reproductive periods. Males reduce food intake during the rut, and energy requirements are high for reproductively active bucks. Dominance displays by bucks, rut snorts, rubbing shrubbery, sparring, front leg kick, escorting, and dominance fights all increase visibility and thus vulnerability. These bucks deplete their fat reserves, and enter the winter in much poorer condition than does. Female requirements are highest during early spring for gestation and the early summer for lactation.

5.1.5 Population growth and regulation

Population growth in its simplest form is regulated by biotic potential. Age of first reproduction, breeding interval, and number of offspring produced all influence the biotic potential of a species. The level of population growth associated with deer biotic potential forms the basis of theoretical deer management, but has only a small place in practical deer management. In practice, managers deal with an "ecologically" limited deer population.

It is necessary to stress the importance of a systems approach to understanding ecological limiting factors. Weather, forage production, predation, inter- and intra-specific competition, deer behaviour, parasites and disease all form a dynamic composite that, when added to the basic biotic potential, creates an ecological potential.

The capacity of any ecological community to support an animal has often been discussed in terms of "carrying capacity." Definitions of "carrying capacity", or "K", are listed in Table 3.

The growth of the population can most simply be approximated as $dN/dt=rN(K-N/K)$, where dN/dt is the population growth rate, r is the intrinsic rate of increase, N is the population size, and K is the maximum population possible (Pearl 1930).

The equilibrium (whether stable or unstable) to which this system settles unaided is defined as the "ecological carrying capacity." The mathematical relationship for a stable equilibrium is depicted in Figure 4.

Typically, managers' definitions of K are lower than ecological K (Figure 4, Table 3): they are functions of the ecological potential of the system and the manager's goals (Salwasser 1976). Deer managers are interested in having a deer herd that is healthy and fecund, that produces large numbers of deer for harvest, and that rebounds quickly from density-independent mortality. At maximum or ecological K, the system is in balance such that births equal deaths. Productivity is close to nil and animal size and condition are depressed. Such a condition of stable equilibrium rarely exists in reality, if at all (see Section 6.2).

It seems least ambiguous to define these variations of carrying capacity as production objectives, than to confuse the concept of ecological carrying capacity. When carrying capacity or K is referred to henceforth, ecological carrying capacity is implied. Deer management is a function of both carrying capacity and the harvest objectives for management of an area. When a population begins to be harvested, the equilibrium density declines and traces an isoclinal curve that represents an equilibrium between vegetation density, animal density, and predator effects (rate of harvest). Along the isocline there will be progressive changes in the attributes of the vegetation (plant density, composition, annual growth removed) and changes in animal attributes (density, condition, fecundity, survival).

The success of a deer's strategies to exploit available habitats will be reflected in its population numbers (as determined by productivity and survival), distribution, and condition.

A different approach to explaining growth and regulation of populations is aimed at estimating net energy gain/loss at the individual animal level (Robbins 1973). The transformation of energy is necessary for sustaining life processes. Anything that an animal does costs something in terms of

TABLE 3. Definitions of carrying capacity

General ecological definitions with limited or no bounding criteria:

1. Weight of animals that can be supported on a given area (Sharkey 1970).

2. An equilibrium resulting from all natural factors (Leopold 1933).

"Food limited" definitions implying a deer/vegetation equilibrium with no external mortality and no predator influence:

3. Maximum population that a given environment can support indefinitely (Keeton 1972).

4. Maximum density of animals that can be sustained in the absence of hunting without inducing trends in vegetation (Caughley 1977).

5. Maximum density of deer that a range can support (Leopold 1933).

6. Greatest number of animals that can be supported on a strictly maintenance basis (Dasmann 1954).

Qualified definitions implying a deer/vegetation equilibrium, a certain standard of animal productivity and health, and harvest. All are lower than ecological K.

7. Optimum K: Stable number of animals that can be supported in good condition on a sustained basis with no range damage (Dasmann 1954).

8. Nutritional K: Size of a healthy and productive population that food resources of a land unit can maintain (Hanley 1981).

9. Economic K: Density of animals that will allow maximum sustained harvest. This is the optimum yield of Caughley (1976).

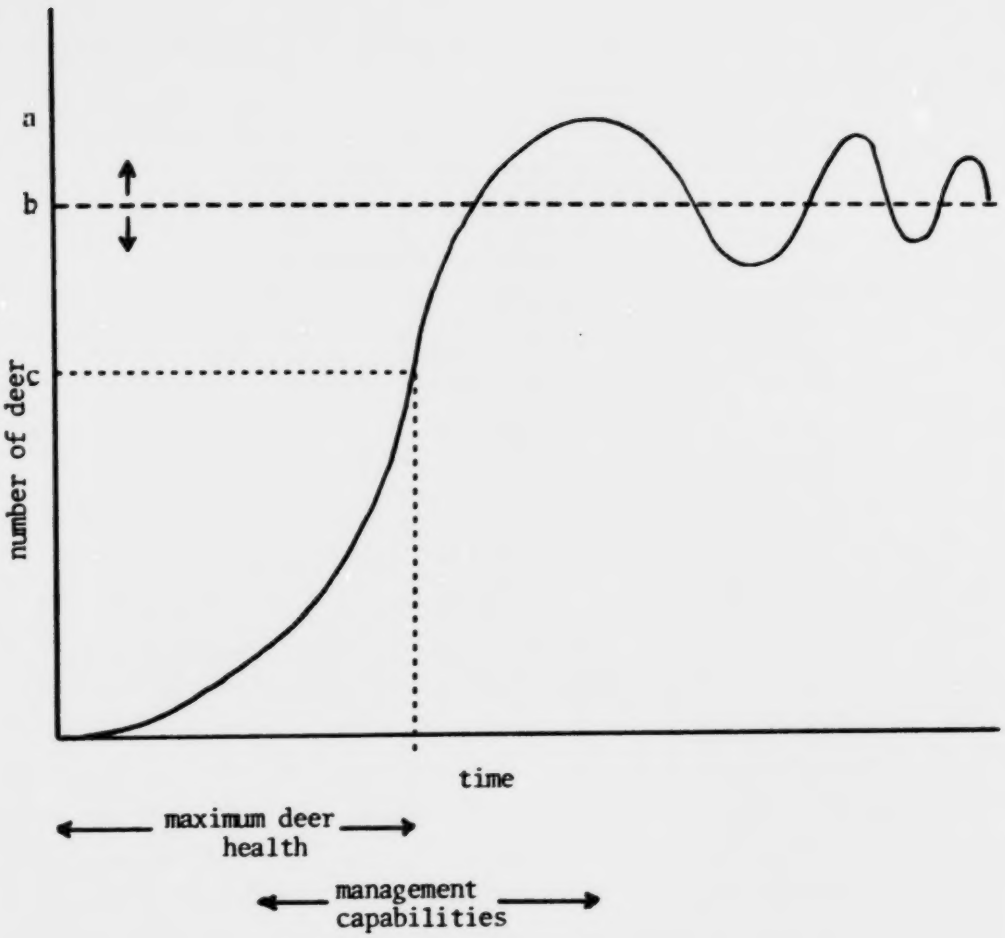

FIGURE 4. Ecological carrying capacity and deer management capacities: a) represents the point of maximum deer density that the environment will support, b) represents stabilized ecological "k", and c) represents maximum rate of production.

energy. The energy requirements of an individual animal is dependent on its basal metabolic characteristics, its activity, and the amount of production occurring (such as tissue growth, gestation, and lactation). The total daily energy requirement is composed of the energy requirements for each of these biological processes. The energy cost equation can be summarized in a variety of ways. Two examples (Moen 1973) are:

1. Total Daily Energy Req. = (basal metabolic energy expenditure) + (activity expenditure) + (production expenditure) + (additional costs to maintain homeothermy)
2. Total Daily Energy Req. = (sum of energy required for bedding) + (ruminating) + (standing) + (feeding) + (walking) + (running) + (breeding) + (social activity) + (production energy)

Energy expenditure for all activities can be compared with BMR and given a rate of energy expenditure expressed as a multiple of BMR, (e.g., running = 8 X BMR) (Moen 1973). When the daily proportion of time spent for each of these activities is considered, the total daily energy expenditure can be calculated. This is a gross simplification of a complex subject but does illustrate the basic approach.

The two approaches, a population carrying capacity and individual net energy acquisition, or some combination of the two, can be used to gauge population growth and regulation. Ultimately it would be those population variables which must be used to gain knowledge concerning deer response to habitat changes caused by intensive forest management. To date, the two approaches are theoretically sound but hard to apply in the field. Direct inventory of deer populations is rarely accomplished (see section 5.2.1) and energy acquisition and expenditure research requires much further effort before managers can use the approach. Trend data and productivity estimates for populations are available, and provided that sampling techniques such as night light counts are continued, rough estimates of population response could be obtained.

5.2 Wildlife Management Context

While Section 5.1 is a general account of deer biology and ecology, Section 5.2 is more specific to the Vancouver Island management situation.

The intent is to make the theory of Section 5.1 more specific to the Vancouver Island situation and then to combine this theory with the particular socio-economic framework of the Island.

5.2.1 Description of the resource

Wildlife populations, especially of coastal black-tailed deer, do not lend themselves to a quantitative inventory. Problems with visibility and high mobility of deer preclude the potential for absolute number estimates. Trend data obtained from reproductive parameters, from night counts, or from pellet group counts are more typical estimates of population status or population description. Although changes with these trend data help us to describe changes in deer numbers (but only in a relative sense), even in this way, the data may only be useful after habitat changes have occurred (MacNab 1983; Potvin and Huot 1983). Even changes in the habitat are hard to quantify and sometimes hard to identify. Managers must perceive changes in the same manner that deer perceive changes.

Ultimately, managers want to relate numbers of deer to quantity and classes of habitat. Traditional methods for attempting to describe the resource in this manner involve confounding factors (Potvin and Huot 1983). Given the scenario where a deer population has low reproductive rates, should the manager blame poor habitat (i.e., low carrying capacity) or overpopulation accompanied with range deterioration?

5.2.1.1 Deer populations: distribution and density

Historical data on black-tailed deer populations on Vancouver Island are meagre. At the turn of the century, Hudson Bay shipping records indicated that deer hides shipped from south Vancouver Island exceeded 20 000 annually. Cowan (1945) estimated deer densities in mature forest to be as low as one per square kilometre or less. This idea persisted till the early 1970's at which time data from numerous surveys in unlogged watersheds indicated mature to overmature forests can support substantial deer populations. There is no evidence to suggest that deer numbers were any different historically than they are today (wolf predation excepted) on the basis of individual habitat type alone (such as mature versus cutovers). Given the extensive logging in recent years (1940-1980), which has produced a higher proportion of young seral stages capable of supporting more deer, the total Island population of deer may be greater than it was before logging.

The population of black-tailed deer on Vancouver Island was estimated in 1979 to be within the range of 150 000 to 300 000 (49% of the provincial deer herd). According to pellet group surveys, deer densities decreased by 50-80% in the Koprino, Nimpkish, Tsitika, Adam, and White river valleys between 1974 and 1980 (Table 4).

Based on all known data on deer populations, the past and present distributions and abundances of deer are illustrated in Figures 5 and 6. These figures compiled in the early 1970's (Figure 5) and 1980 (Figure 6) indicate that, while the overall distribution of the species remains unchanged, the abundance has varied. South Island numbers appear to be up (prior to the 1981/82 winter), probably due to the recent series of mild winters during 1976 to 1980, while North Island numbers are down due to wolf predation and possible habitat degradation (Hebert et al. 1981; Hatter 1982; Jones and Mason 1983).

Relative differences and changes in deer density have been measured almost entirely from pellet group surveys (Table 4). These surveys indicate densities in unlogged watersheds vary from less than one deer per square kilometre on the southwest coast to 12 deer per square kilometre in a number of unlogged watersheds on northern and central Vancouver Island (Table 4). Densities in partially logged watersheds have exceeded 20 deer per square kilometre. Generally, pellet group surveys indicated densities of deer in partially logged areas to be 50-100% greater than in unlogged areas (Nimpkish or Adam versus Tsitika). Further, densities in advanced second-growth forests, such as the Sayward Provincial Forest, tended to be 20-30% of densities in unlogged, old-growth forests (Table 4).

Densities of deer on Vancouver Island appear to be similar to those observed in Washington and Oregon, slightly lower than those in California, and higher than those in Alaska (Table 5). It is difficult to make realistic comparisons because observed deer density can vary tremendously with such factors as successional stage, amount of logging, severity of previous winter, hunting and predation pressure, and observer biases.

5.2.1.2 Deer habitat: present status and capability

The present status of deer habitat is known in general terms for most of the Island, but in specific terms for only a small proportion of it. The rate and wide extent of logging and other forestry activities make it difficult to keep an up-to-date inventory of habitat.

TABLE 4. Deer density in various Vancouver Island watersheds based on pellet group surveys. (Watershed unlogged = N, partially logged = L, advanced second growth = SG).

Area	Watershed	Deer - years/km^2 [1] Early 1970's	Late 1970's	Percent change	Source (s)
North Coast	Klootchlimmis(N)	--	12	--	Townshend 1980
	Koprino(N)	10	2	- 80%	Davies 1975, 1978a
	Stranby(N)	6	--	--	Davies 1974e
	Wanokana(N)	--	2	--	Davies 1978b,c
N.W. Coast	Klaskish(N)	8	8	- 0%	Davies 1974a, 1979
	Quoukjnish(N)	10	--	--	Townshend 1977a
	Power[2] (N)	--	20	--	Townshend 1977a
	Tahsish(N)	8	--	--	Townshend 1975, 1977b van Drimmelen 1977
	Tulpana(L)	10	--	--	Leigh-Spencer 1974
	Zeballos(L)	12	--	--	Leigh-Spencer 1974
Nimpkish	Shoen/Cain Mountain(L)	30[2]	9[2]	- 60%	Jones 1975,1978 Davies 1978b
		18	4	- 80%	Townshend 1980
N.E. Coast and Interior	Adam(L)	16	8	- 50%	Davies 1978b,c
	Claude Elliot(N)	12	4	- 70%	Davies 1974a, Jones 1978
	Nisnack(N)	8	--	--	Davies 1974b,c
	Tsitika(N)	12	4	- 70%	Davies 1974d Jones 1978 Moir 1979
	White(L)	12	5	- 60%	Moir 1972 Davies 1974b, 1978b
Sayward Forest	Mohun/Campbell(SG)	--	3	--	Townshend 1980
East Coast	Northwest Bay(L)(SG)	25	10	- 60%	Gates 1968 Kale 1976 Davies 1978b
	Nanaimo River(L)[2]	--	30	--	Townshend 1980
	Cowichan(SG)[2]	10	10	- 0%	Davies 1980
S.W. Coast	Clayoquot(N)	--	<1	--	Moir 1977b
	Klanawa(L)	--	<1	--	Moir 1977a,c
	Megin(N)	<1	--	--	Davies 1974c
	Nahmint(N)	<1	--	--	Davies et al. 1976
	Toquort(N)	<1	--	--	Janz and Nyberg 1973
	Walbran(N)	--	<1	--	Moir 1977d

1 Deer - years/km^2 = $\frac{\text{\# pellet groups}}{\text{m}^2} \times \frac{10^3\ \text{m}^2}{\text{km}^2} \times \frac{1\ \text{year}}{365\ \text{days}} \times \frac{1\ \text{deer-day}}{13\ \text{pellet groups}}$

2 Pellet group surveys conducted on wintering areas only.

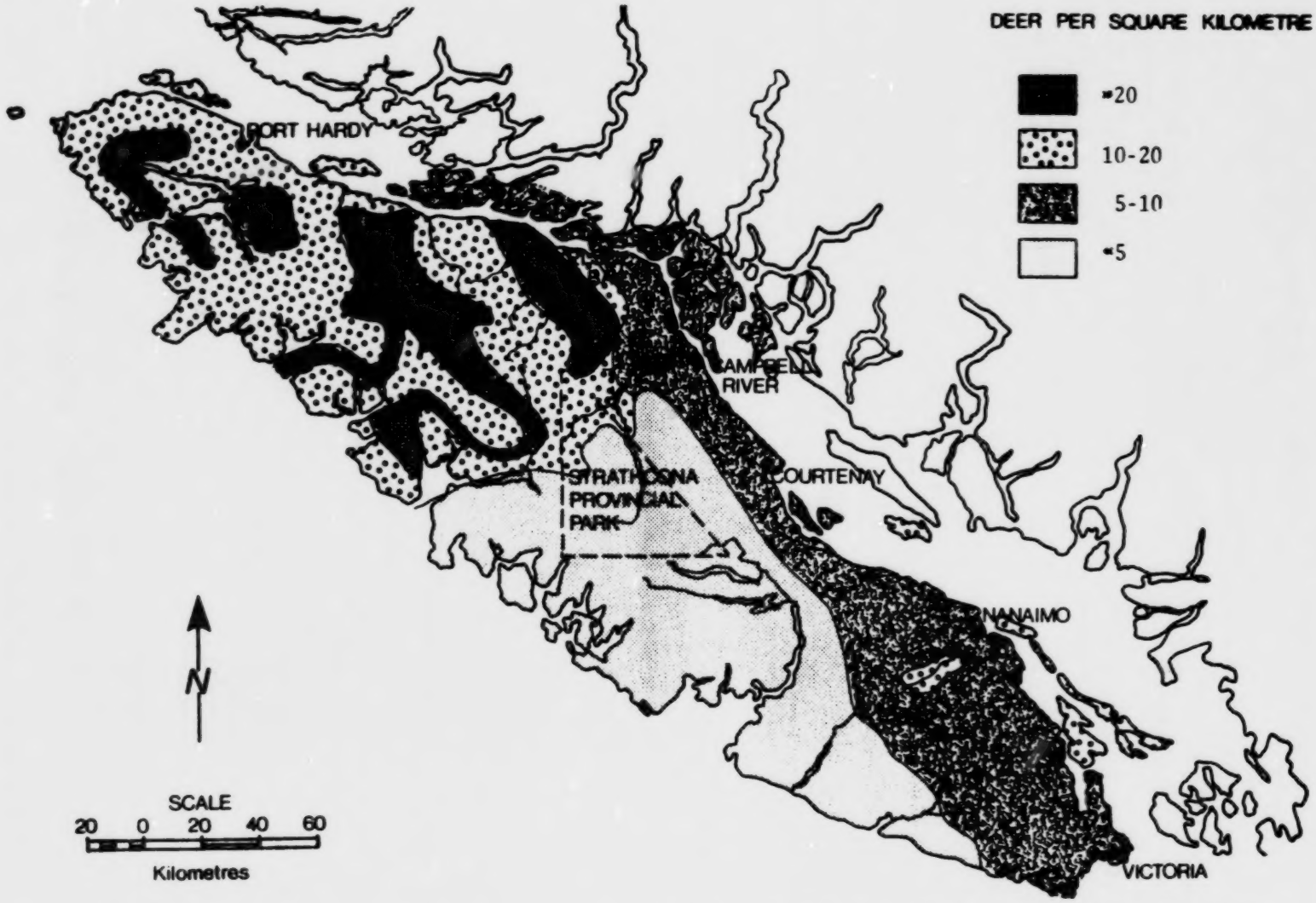

FIGURE 5. Estimated distribution and abundance of black-tailed deer on Vancouver Island (1968-1974).

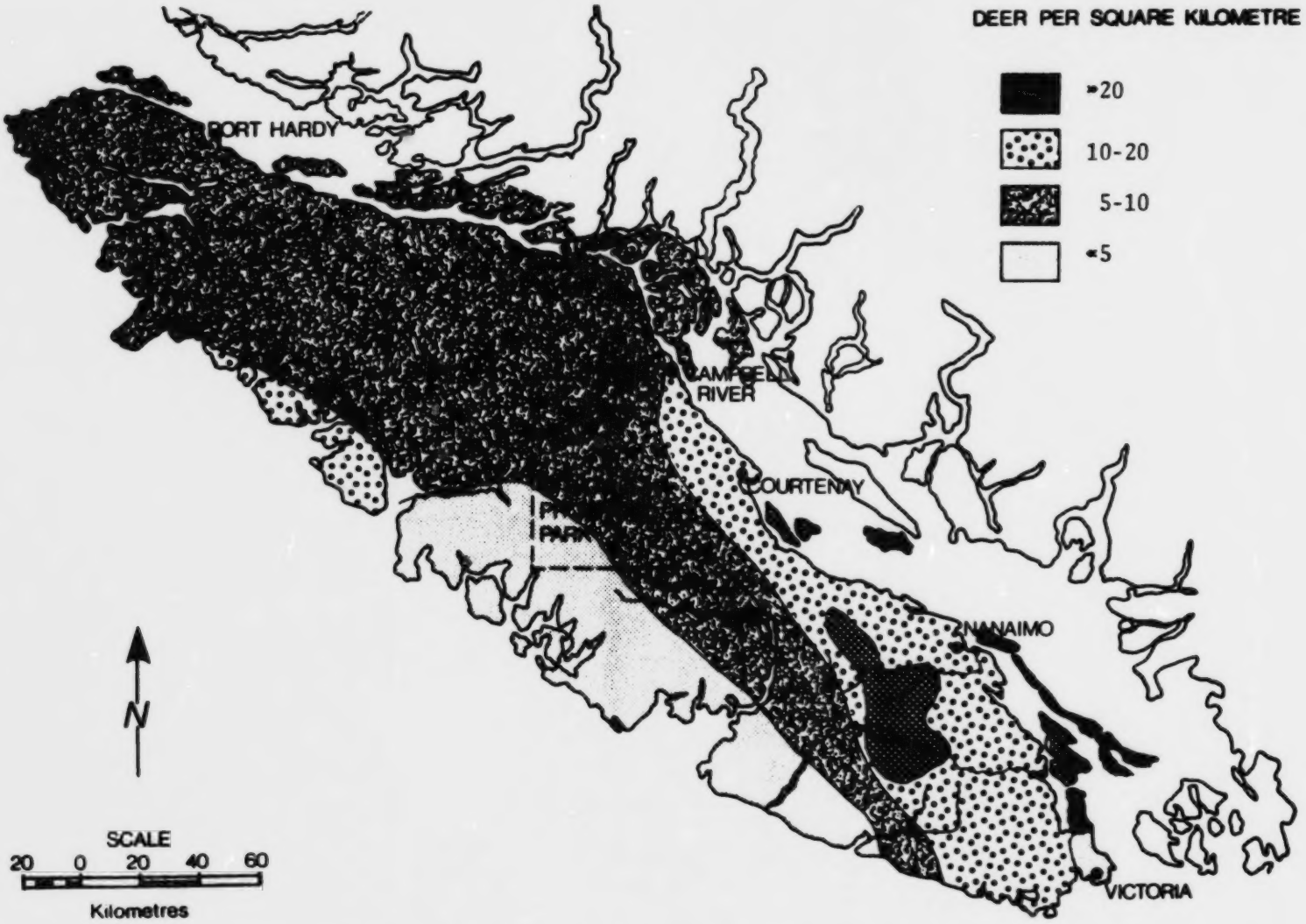

FIGURE 6. Estimated distribution and abundance of black-tailed deer on Vancouver Island (1980).

TABLE 5. Densities of black-tailed deer in cutover habitats of the Pacific Northwest

Location	Number of deer per km^2	Reference
Vancouver Island		
Southeast Coast	19 - 23 (average)	Robinson (1958)
Northwest Bay	16 - 30 (average)	Gates (1968)
	10 - 20 (average)	Kale (1976)
Nimpkish	15 - 20 (average)	Willms (1971)
	40 - 80 (spring range)	Jones (1972)
Adam River	16 - 25 (average)	Davies (1974b)
White River	10 - 20 (average)	Davies (1974b)
Washington	19 - 20 (average)	Brown (1961)
Oregon		
Tillamook Burn	12 (average)	Einarsen (1946)
	23 (average)	Crouch (1968)
	21 (average)	Hines (1975)
California	17 - 31 (average)	Anderson et al. (1974)
	37 (average)	Bonn (1967)
Alaska	5 - 10 (average)	Schoen and Wallmo (1978,1979)

Cover

Forest harvesting on Vancouver Island directly modifies "cover" for black-tailed deer. The impact is usually in the form of large-scale clearcuts and as such would probably affect all three aspects of cover: thermal cover, security cover, and cover from deep snow.

On Vancouver Island, cold chilling conditions may be important. Bunnell (1979) suggested that deer on Vancouver Island bear no significant thermoregulation costs in winter. This simply means that thermoregularity costs over and above those that the deer can cope with are not a concern; and secondly, that deer do not appear to respond physiologically (with increased metabolic rate) unless the microclimate change is very severe. The combination of cold, wet spring weather, however, may provide a thermoregulatory problem for deer. The "effective temperature" is expected to be much lower due to the moisture.

How forest harvesting affects security cover is not known. Since wolf populations on Vancouver Island have increased concurrently with increased forest harvesting and decreasing deer populations, it is not known to what extent deer need security cover or even what constitutes security cover.

The fact that deer use old-growth forests for cover from deep snow is well documented for Vancouver Island (Jones 1974; Weger 1977; Harestad 1979) and for southeast Alaska (Bloom 1978, Wallmo and Schoen 1980). Prior to wolf population increases on Vancouver Island, shelter from snow was considered the primary limiting factor to Island deer populations. Current research has followed a course from literature review and data synthesis (Shank and Bunnell 1982a, 1982b; Jones and Mason 1983; Bunnell et al. 1985; Nyberg 1985) to research proposals (Bunnell 1984; Nyberg et al. 1985a), and finally data collection which is currently in progress under Phase I of the IWIFR project (Section 1). Although other aspects of deer ecology are considered, the major goal of ongoing research directly addresses the issue of cover from deep snow (Nyberg et al. 1985a). General objectives are to understand when deer select cover from snow, what characteristics of cover appear most important, and, through adaptive management, how forestry practices modify those important aspects of cover (Nyberg et al. 1985a).

Nutrients

Food habits and forage selection are well documented for black-tailed deer on Vancouver Island. Generally, food habits vary tremendously between areas and seasons both in terms of species composition and relative proportion of species in the diet (see Section 5.1.2.5 for detail). Protein levels of deer forages on Vancouver Island (lichen excluded) range from 5-13% (Gates 1968; Rochelle 1980; Ellis 1984), and thus it would appear that at lower levels, protein content could be limiting. However, recent research on urea recycling in wild ungulates (deer and elk) (Robbins et al. 1974; Mould and Robbins 1982) has resulted in a decreased concern for protein as a limiting nutrient (modified from Nyberg 1985).

On Vancouver Island estimates of forage availability for deer are limited to a few studies in two areas on Vancouver Island: the southeast coast (Cowan 1945; Gates 1968) and the Nimpkish Valley (Harestad 1979; Rochelle 1980). These studies provide estimates for old-growth and young seral stages, but little data on older regenerating stands. (For a review of forage production estimates, see Nyberg [1985]). The work and resultant estimates are only sufficient for making some broad generalizations about stand type and forage production (i.e., some old-growth stands provide more forage than some clearcuts and older regenerating stands appear to provide less forage than either old growth or clearcuts) (Nyberg 1985). Much more work, both on inventory and research, will be required to derive estimates sufficiently reliable to assess habitat quality on the basis of forage availability.

Over most of Vancouver Island forage availability is also influenced by snow. Dependent on regional climate and topography, snow accumulations restrict the availability of habitat during the winter season, and thus limit food availability. Snow also buries forage. The actual reduction in forage availability due to burial depends on both species composition and species growth forms in the understory (Harestad 1979). In some situations, forage species also differ in quality, with the shortest plants generally having higher quality. Burial by snow, therefore, can also cause a reduction in quality of the total forage. Elevation, slope, and aspect are important in determining deposition,

accumulation, and melt of snowpacks, thus indirectly influencing seasonal availability of range and seasonal distribution of deer.

Lichens have been identified as a major component of deer winter diets (Cowan 1945; Gates 1968; Jones 1975; Rochelle 1980). Cowan and Rochelle both reported values of lichen content being approximately 36% of rumen volume in winter. In mild winters Jones and Gates reported the content as 10-11% of the rumen volume. Although, managers recognize lichens as an important constituent of black-tailed deer winter range, it is not understood how lichen abundance could be managed in second-growth forests.

Stevenson (1978) assessed abundance of lichen biomass in old-growth stands on Vancouver Island. A visual estimate technique based on an estimate of lichen cover and crown length of trees provided a sufficient technique for coastal forests. Current efforts are aimed at: 1) evaluating lichen abundance and deer winter habitat selection; 2) reviewing inventory methods for quantifying lichen abundance; and 3) producing a problem analysis concerning the potential to introduce and propagate lichens in young, second-growth forests as an available winter forage for deer.

Temporal and spatial variation

Temporal and spatial variations in the physical environment were identified as potential influences on deer and deer populations (Section 5.1.1.3). The best discussions on this subject to date are provided by Wallmo and Schoen (1980) and Bunnell et al. (1985). Of primary concern is the inter- and intra-winter variation in weather. Spatial variation appears to be important at two levels: 1) the watershed level (e.g., proximity of spring forage areas to winter habitat: number and distribution of winter ranges; and 2) the seasonal habitat level (e.g., spatial distribution of snow in winter ranges).

Current information about spatial and temporal variations in a deer's physical environment for Vancouver Island is meagre and simply descriptive, centering exclusively around snowpack accumulation patterns.

The primary factors restricting the physical availability of habitats are snow (Section 5.1.1.3) and forestry activities, which can totally remove habitats (by harvest) or physically preclude their use because of debris barriers. Deer responses to these physical

restrictions on habitat availability are obvious: deer do not use the area, or they move away, a response which, if prompted by snowpacks, is observed as a seasonal movement or migration.

Below 300 m elevation on Vancouver Island, snow is ephemeral and the total range is available to deer except in the most severe winters. Above 1000 m deep snowpacks are present in most winters. Deer are restricted below this elevation for 3-6 months, most often below 800 m. Above 300 m is referred to as "mountainous", inferring frequent snow and an apparent need for winter range in the 300- to 1000-m elevation range.

Slope also influences snow depth (vertically) and thickness (perpendicular to slope) by its effect on the ratio of surface area to horizontal area (Bunnell 1978; Bunnell et al. 1985).

With increasing slope steepness, a given amount of snowfall is distributed over an increasingly large area, resulting in a greater proportion of the snowpack being exposed to air and radiant energy. All other things being equal, the rate of snow ablation (melt) will be proportional to surface area. Over the course of the winter, snow accumulation will generally be negatively related to slope angle.

Aspect is also very important. South aspects are exposed to more solar radiation than are north aspects. Radiation increases with steepness of slope on south aspects and decreases on north aspects. Snow ablation varies accordingly. Thus, it might be expected that steep south slopes are usable longer in fall, winter, and spring than are shallow south slopes or any north slopes.

Considering the low sun angle at northern latitudes during winter and the steep topography of much of Vancouver Island, shading of the slope by adjacent mountains is another factor to consider. Unshaded, south-facing slopes may have less snow than shaded slopes, and therefore could provide more accessible green forage.

In summary, on Vancouver Island, topography potentially can have a large influence on the distribution of winter snowpacks and the resultant restricted range available to deer. The distribution of winter deer use in high snowfall areas of Vancouver Island as determined from total watershed pellet group survey does indeed appear to be related to snowpack distribution. The highest deer use was found on steep, unshaded, southerly aspects (from surveys in Tsitika, White, Adam, Nisnack, Northwest Bay; see Table 4).

In the mountainous areas of Vancouver Island the winter snow accumulations would limit deer populations below forage carrying capacity. Many authors (Bunnell et al. 1978; Harestad 1979; Hanley 1981) have provided the following argument: If wintering capabilities of an area are modified adversely by timber harvesting, spatial patterns of deer habitat use may shift. Harvesting results in lowered quality of some areas and raises the relative quality of the remaining winter range areas. If the net effect is to concentrate deer to a density greater than the forage carrying capacity, then the relative value of the forage within winter ranges will decline.

Summary

The following summary describes the status of deer habitat in terms of general logging patterns for those parts of the Island where the expected demand for deer will be moderate to high (see Section 5.2.2). Expected low demand areas are excluded.

a) Southern Vancouver Island (Victoria to Campbell River)

Most old-growth forests have been liquidated in the Douglas-fir and Dry Western Hemlock Biogeoclimatic Zones, with the remaining logging activity concentrated in the Wet Western Hemlock and Mountain Hemlock Zones. Few old-growth winter ranges remain. Options for maintaining static level deer populations in the higher snowfall portions of this area are limited. Presently most potential deer wintering areas in these higher snowfall areas consist of very young second growth (5-30 years) that will not likely have much wintering capacity for many years. Short-term options for enhancing second growth for winter range exist only at elevations below 400 m near the coast. Older, second-growth stands (50 + year) are more prevalent in these lower elevations.

b) Central Vancouver Island (area bounded by Campbell River, Gold River, Port Alice, and Beaver Cove)

The Wet Douglas-fir and Dry Western Hemlock Subzones have been logged extensively, particularly in the Sayward Forest, the Salmon River valley, and the Nimpkish River Valley. Most old growth on the low coastal plain area has been cut, and logging is now at higher elevations into the Wet Western Hemlock Subzone. Most areas have a considerable number of years of logging left, but low-elevation winter logging is in short supply. A portion of the deer winter ranges has been maintained;

thus some deer populations may be retained in high snowfall areas. Options for immediate enhancement of second growth for deer winter range are again limited to low elevations, that is, low snowfall areas. Many winter ranges in higher snowfall areas have been logged recently so that regeneration is only 5-10 years old or in the case of the Sayward forest, 20-40 years old. Some cutovers adjacent to winter ranges are being considered for silvicultural manipulation to produce spring forage.

c) North Vancouver Island (Port Hardy Area)

Logging has been extensive in the Port Hardy, Holberg, Port Alice, and Port McNeil quadrangle. Most of the higher quality stands have been logged, and forest companies are now exploiting lower quality stands. Winter ranges have been protected where necessary. Enhancement of second-growth stands for deer will likely be limited to a few spring forage areas at higher elevations and possibly some lower elevation areas in the Wet Hemlock Subzone.

d) Opportunities to enhance second growth for winter range

An examination of recent Tree Farm Licence (TFL) management and working plans (#7,#39, #37) and some rather dated forest stand data for all MacMillan Bloedel Divisions on Vancouver Island (B.C. Wildlife Section files, Nanaimo) indicated that less than 20% of the second-growth stands exceeded 50 years of age and less than 2% exceeded 100 years. Additionally, most of the 50^{+}- year-old stands were located at very low elevation (i.e., low snowfall areas). Work by numerous investigators (Jones 1974; Kale 1976; Harestad 1979) has suggested that second-growth stands, if left to develop undisturbed will not attain the necessary deer winter range characteristics (i.e., lichen abundance, uneven age canopy, snow accumulation and ablation patterns, litterfall, forage abundance and diversity) for 200 years or more. It may be possible to hasten the attainment of these characteristics via silviculture. (e.g. Nyberg et al. 1985b). The viability of this option in moderate snowfall areas is high if it can be demonstrated that 50- to 80-year-old stands can be made to provide adequate winter range. One of the focuses of the IWIFR project will be to see if winter range can be developed in young stands (Nyberg et al. 1985b).

The original 1:50 000 Canada Land Inventory (CLI) maps have not been upgraded or corrected, but Figure 7 illustrates the current thinking within the B.C. Wildlife Section about Island-wide deer production capabilities. Capability was determined by considering the estimated densities of deer in old-growth watersheds versus logged watersheds. Intra-specific competition and the influence of predation were not considered.

5.2.1.3 Deer predators

The major predators of deer on Vancouver Island are wolf, cougar, and black bear. Wolves are by far the most important predator and, in light of recent investigations, appear to be limiting deer numbers (Hatter 1982; Jones and Mason 1983). Most influence from predators to date has occurred in the northern Vancouver Island region. Based on sightings, distributions, and the hunter sighting index, wolf numbers have increased during the 1970's and early 1980's while deer numbers have decreased (Atkinson and Janz 1983).

Although wolves are suspected to be limiting deer populations, the nature of the predator-prey system remains unclear (Section 5.1.2). Presently there is no direct information that predators, such as wolves influence seasonal movements and habitat selection by deer (Hatter 1982; Jones and Mason 1983). Jones and Mason (1983) suggested that increased wolf activity did not appear to change the nocturnal use of cutovers by deer in the Nimpkish Valley. The actual need for escape or hiding cover and the spatial aspects of escape cover and feeding require more investigation (McNamee et al. 1981). A more specific discussion on problems concerning the Vancouver Island wolf-deer interaction is given by Hatter (1982).

5.2.1.4 Competition

Competition between deer and their conspecifics on Vancouver Island is probably infrequent, but it is possible that local problems exist. These conflicts occur when "islands" of prime habitat remain following some ecologically catastrophic event (e.g., fire or logging).

Inter-specific competition may arise between elk and deer on deer winter ranges, as well as on spring forage production areas. The White and Adam watersheds and the Nimpkish Valley all experience elk and deer range overlap, particularly on prime deer winter ranges, which suggests competition. Deer and elk in the Power River watershed on the west coast of Vancouver Island

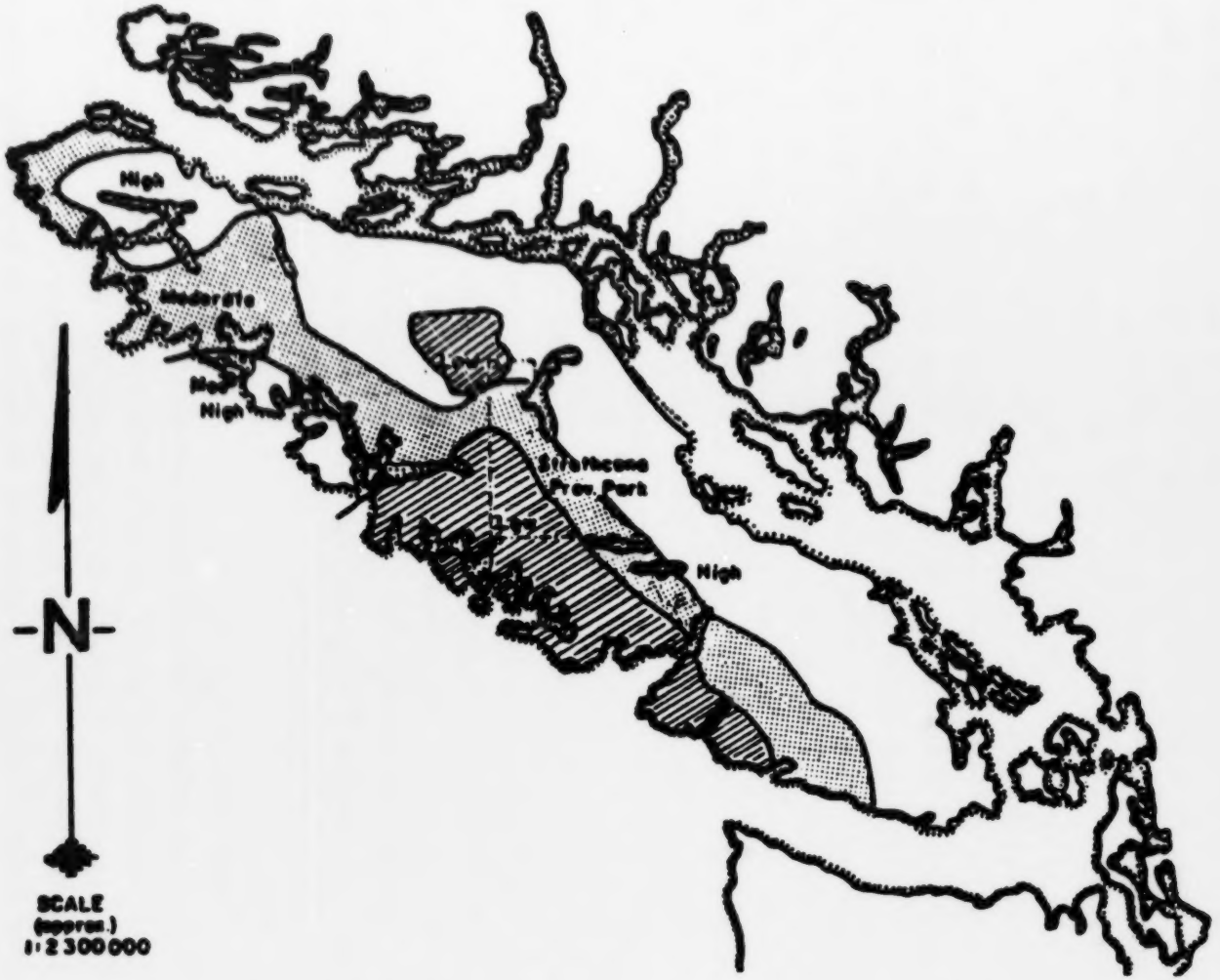

FIGURE 7. Apparent capability of Vancouver Island to support deer (from Nyberg 1985).

also experience competition. The significance of the competition with respect to depletion of the resource base is unclear. No quantitative data exist to enable evaluation of the competition that occurs in the Nimpkish and Power river watersheds.

5.2.1.5 Behaviour

The following discussion concerning behaviour of Vancouver Island black-tailed deer comes from four sources: Gates (1968); Jones (1975); Harestad (1979); and Rochelle (1980). Quantitative data exist only for food habits and seasonal home range selection. Knowledge about courtship, response to physical environment, and anti-predator strategies is anecdotal at best.

Habitat selection and home range

Selection for old-growth timber as cover is well documented in the situation where only open clearcut habitat or old-growth habitat types were available during winters with high snowfall (Jones 1975; Harestad 1979). Ongoing studies indicate this same selection exists when young second-growth habitat is available as well (Doyle et al. 1985). No information is available from locations where deer have the potential to select from open, young second-growth, older second-growth, or old-growth habitat types. Some of the older second-growth stands provide adequate snow shelter but provide little forage. Although selection is thought to be based on factors relating to reduced snow depth, the importance of other parameters such as thermal cover, security cover, and forage availability is still unclear. No study to our knowledge has provided quantitative data regarding security cover or thermal cover. It is also important to note that seasonal movements such as migration may be related to such variables as seasonal differences in food supply, although there appears to be a large learned or inherent basis for the behaviour (Harestad 1979). Preliminary evidence suggests that site fidelity may override specific habitat selection regardless of winter condition.

Home range use and habitat selection were described by Harestad (1979) for five deer on northern Vancouver Island. Home range size varied considerably among individuals, but a consistent decrease in size from summer to winter ranges occurred. Similar patterns have been

observed in the study under progress in the Nanaimo River region of Vancouver Island (Doyle et al. 1985).

Harestad (1979) found deer to use home ranges rather than territories and commented further that this confirms predictions by Geist (1974) concerning the spatial organizations of ungulates in environments with seasonal fluctuations in availability of resources.

Predator avoidance

Little or nothing is known regarding Vancouver Island black-tailed deer predator avoidance strategies, or even if they have any.

Food habits

Food habits of black-tailed deer are best summarized by Rochelle (1980) (Figure 8). Jones (1975) found that conifers, shrubs, and lichens occurred in 50% of the rumen samples taken during a severe winter. During a mild winter, ferns and forbs occurred in 50% of the rumen samples in addition to conifers, shrubs, and lichens. Rochelle (1980) described black-tailed deer as opportunistic feeders since a relatively high consumption of forage items (such as shrub berries and fungi) were available for only short periods of time.

5.2.1.6 Growth and regulation

The two theoretical bases for explaining population growth and population regulation outlined in Section 5.1.5 (i.e., carrying capacity and net energy gain/loss) have rarely been applied to Vancouver Island deer. Jones and Mason (1983) used reproductive parameters, night counts and pellet group counts to evaluate growth and reproduction of northern Vancouver Island deer populations. The following aspects of carrying capacity were assessed: 1) predation by wolves and human hunters; 2) cover changes caused by forestry activities, and 3) climatic dynamics of the physical environment. Population trends indicate that annual recruitment was initially high, but later reduced by the severe winters of 1968-69 and 1971-72. Despite subsequent mild winters which allowed populations to rebound, pressure by wolves and hunters is believed to have kept numbers relatively low. Wolf activity was negatively correlated with a 75% reduction (occurring over 6 years) in deer numbers (Jones and Mason 1983). Currently deer number indicies remain low, indicating approximately 2-9 deer per square kilometre in most northern Vancouver Island watersheds (Table 4).

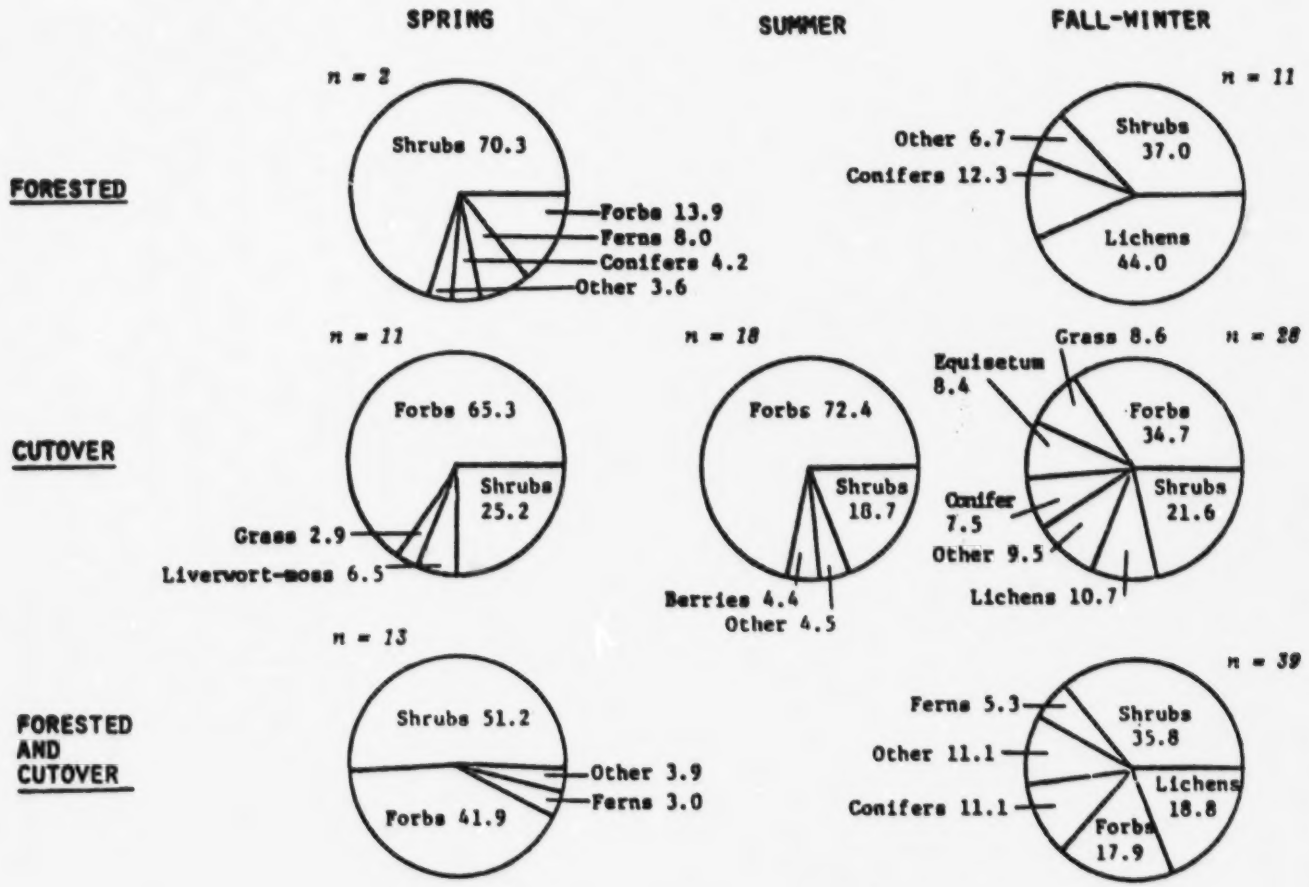

FIGURE 8. Seasonal importance values (%) for forage types consumed by black-tailed deer in forested and cutover habitats. Importance value is the product frequency of occurance and percent volume. Percent importance value is the importance value of individual types divided by the sum of importance values for all types (from Rochelle 1980).

The "net energy" approach to date has been primarily in the form of conceptual models, and thus its discussion is reserved for Section 5.4.2. It should be pointed out, however, that the energy approach is best suited for predator-free environments unless predation rates are well defined.

In recent times, old-growth logging (causing extreme temporal and spatial changes in cover and available nutrients), a few irregularly spaced, severe winters, and increases in wolf populations have produced extremely complex and poorly understood changes in Vancouver Island deer numbers.

On Vancouver Island it is clear that the recent increases in wolf populations are now seriously limiting deer populations (Jones and Mason 1983). Shelter from snow, as well as winter forage availability and quality -- either alone or as modified by snow, are other major factors limiting deer populations. The abundance, distribution, and quality of forage resources fluctuates seasonally, being most abundant in summer and least available in winter. The deer's body reserves accumulated prior to winter, and the rate of depletion of these reserves over winter, determine the welfare of the deer. If wolves and hunters were absent from the snow-free coastal areas of Vancouver Island, then forage quantity and quality would probably limit deer. There is no direct evidence at this time to suggest that summer or fall food resources are limiting to Vancouver Island deer.

5.2.2 The nature and extent of public demand: past, present, and projected

Public demand for deer is primarily for recreational and guided hunting, with the latter representing only about 5% of the current estimated harvest of deer. Other demands include non-participatory, non-consumptive, and genetic conservation.

Demand and use of deer is assessed by four measures: harvest, number of hunters, number of hunter days, and hunter success (deer per hunter or deer per hunter day). These data are derived from the hunter sample (a voluntary mail questionnaire), regional game or road checks, and access or gate records kept by logging companies. In combination, these sources of information indicate changes in harvest and hunter effort.

From a provincial perspective, Vancouver Island has, over the period of 1960 to 1980, contributed an average of > 40% of the provincial deer harvest. Island deer hunting has accounted for 35-50% of the provincial recreational hunting days spent on deer.

Since 1950 the Vancouver Island deer harvest has varied between 5000 and 28 000 deer, averaging 16 400 ± 1060 (X ± S.E.) (Figure 9). The distribution of the harvest has also varied over the past 20 to 30 years (Figure 9). In the mid 1960's, 80% of the harvest was from the south half of the Island, and 20% from the north half. By the early 1970's, the north half's proportion of the harvest was 60%. During the mid and late 1970's, deer herds and harvest declined dramatically on the north Island coincident with a large increase in wolves (see Section 5.2.1.6), so that by 1984, the north Island contributed only 20% of the harvest.

The number of hunters on Vancouver Island fluctuated around 20 000 between 1960-1980 but has declined to 14 000 since 1980 (Figure 9). Approximately 78% of these hunters reside on the South Island (hunter questionnaire data). For 1976 to 1984, the years for which we have data specific to management units, the proportion of Vancouver Island hunters who hunt the north Island declined from 60 to 30%. The proportion of south Island hunters who travelled north to hunt dropped from 37% in 1976 to 20% in 1984.

The data on hunter days spent on Vancouver Island for all seasons are limited to 1976-1984. During this period hunter days increased from approximately 140 000 to 190 000 in 1982 but has returned to 140 000 in 1984. The proportion occurring on the north Island dropped from 40 to 25%, as might be expected from the changes in distribution of hunters.

Hunter rates of success have declined all over Vancouver Island from 6 to 8 days to bag a deer in the 1960's, to 15-20 days required in the early 1980's. On the north Island the decline has been more recent and pronounced (Figure 9).

In summary, the number of hunters remained essentially constant on an Island-wide basis for 20 years, but has dropped in recent years; deer harvest has declined mostly on the north Island; hunter effort (measured in days) has fluctuated considerably, and has shifted to the south Island; and hunter success rates have declined in all areas of Vancouver Island over the last 10-15 years.

Projected demand for deer in the next 10-20 years and beyond are now being prepared. Present projections, though only in general, suggest that in the next 5-10 years harvests are likely to continue declining. One reason is that south Vancouver Island areas did not have sufficient amounts of winter range to support the deer population in the moderately severe winter of

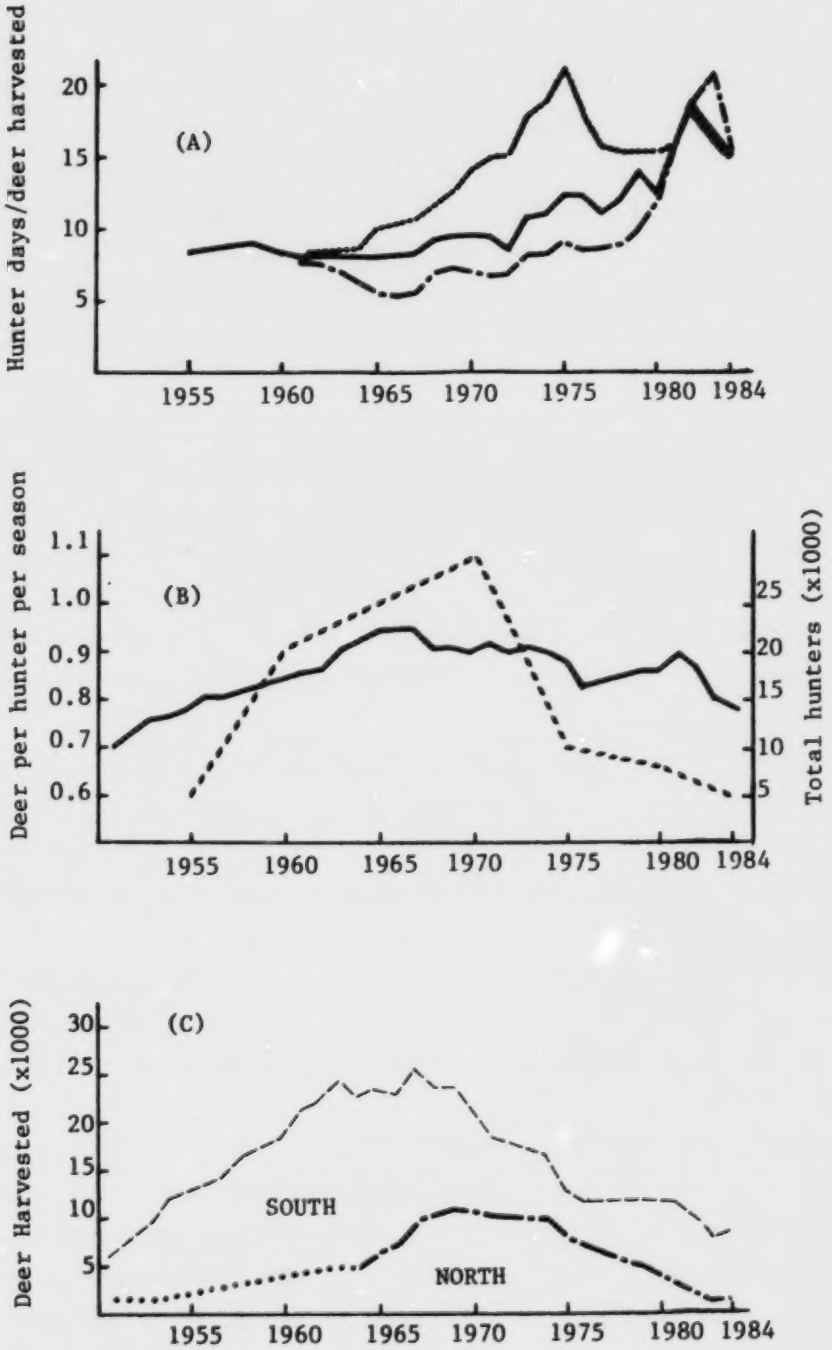

FIGURE 9. Hunter/harvest/success trends on Vancouver Island from the early 1950's to 1984: (A) Hunter effort (days/deer) for south island (·····); north island (——·——); and total island (————); (B) Season success (deer/hunter) (- - - - -) and total hunters (————); and (C) Total deer harvested for the Island (— — — — —); proportioned by north and south Islands. Estimated trends are depicted by (·····).

1981/82, and approximately 30% of this population died (B.C. Fish and Wildlife surveys - spring 1982). Another reason is that wolves are presently increasing on southern Vancouver Island and deer numbers may decline as they did on the north Island during the mid 1970's (Hebert et al. 1981; Jones and Mason 1983). On the north Island, harvests and deer populations will likely remain low or even decrease further unless wolves become less plentiful and unless present winter ranges are preserved.

Despite these forecasts it is expected that potential demand for deer will increase gradually. This expectation is based on a constant participation rate for recreational hunting and a projected increase in the human population of Vancouver Island and the Lower Mainland.

Non-consumptive use will likely be greatest within easy travelling distance of population centres, and in or adjacent to parks or other major public recreation areas.

Consumptive users will no longer be able to exploit either large deer herds, such as those of the 1950's and 1960's, or a continual supply of newly accessed or logged areas. Future demand will depend less on this exploitive type of hunting and more on factors such as traditional hunting habits, travel costs, aesthetics, reasonable access, and the capability of an area to produce deer for harvest.

Approximately one-third of Vancouver Island will contribute little towards meeting anticipated demand for deer (Figure 10). This one-third consists of:

1. areas of Vancouver Island where hunting is severely restricted or is not allowed, as in parks and in high-growth urban areas on the east coast and Gulf Islands,
2. areas where access is extremely restricted (usually to boats only) such as off-shore islands and a large portion of the rugged west coast between Barkley Sound and Quatsino Sound, and
3. areas of demonstrated low capability for supporting substantial numbers of deer. This includes the southwest coast of Vancouver Island from Muchalet Inlet south, to just north of Port Renfrew. As well, half of this area is restricted access.

The remaining two-thirds of Vancouver Island can be rated as low, moderate, or high-demand hunting areas on the basis of capability, location relative to population centres, and attractiveness for hunting. Figure 10

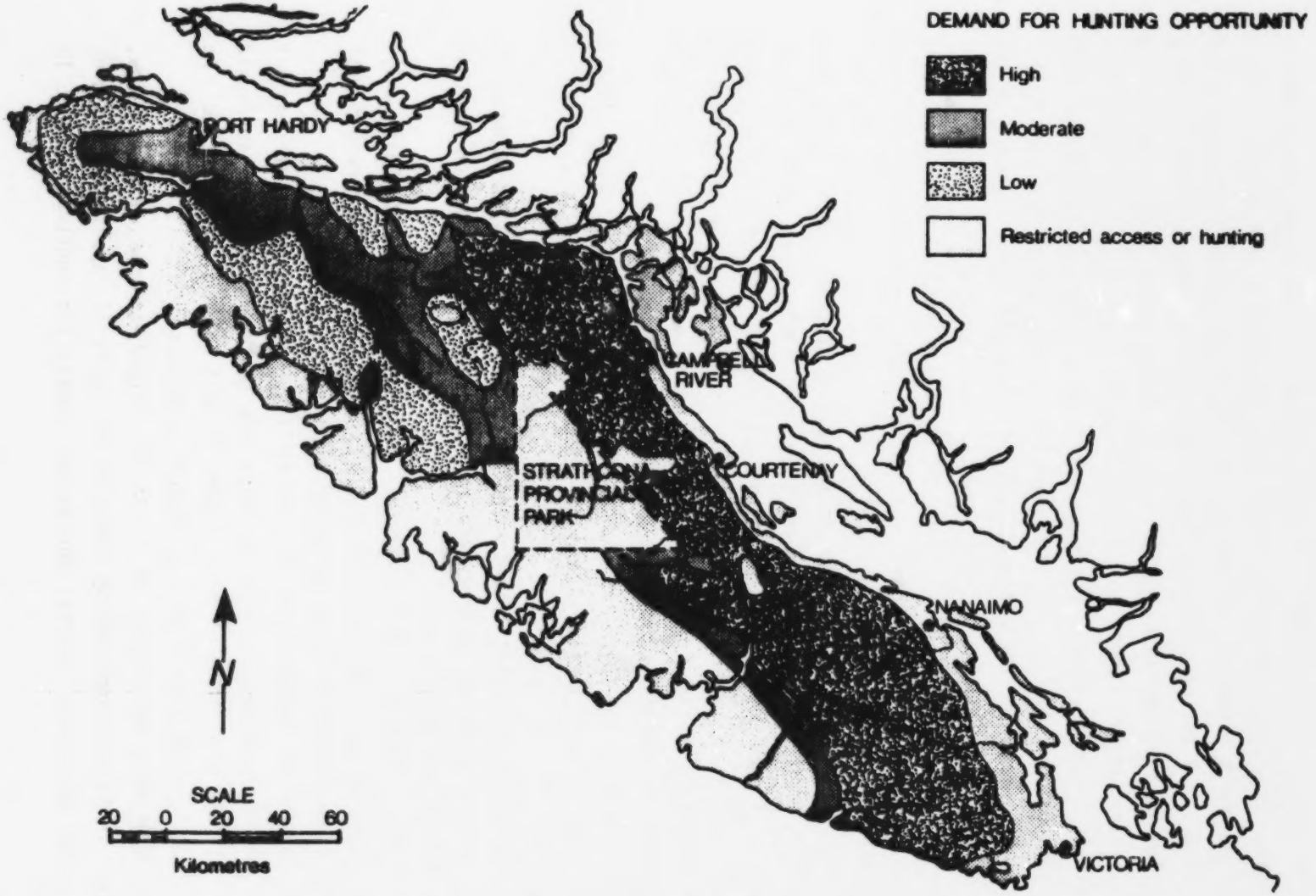

FIGURE 10. Anticipated demand for deer hunting on Vancouver Island.

illustrates the current thinking about future hunting demand for deer on Vancouver Island.

5.2.3 Goals and objectives

Provincially, the first objective is to increase the deer population from 425 000 to 475 000 animals distributed in their present range; the second is to provide 900 000 hunter days of recreation with an annual kill of 60 000 (15 days per deer harvested); and the third is to provide opportunities for people to view deer in natural habitats. All three objectives seek to meet societal needs, especially consumptive demands. The projected increase in deer populations assumes a like increase in demand.

The management objectives for Vancouver Island black-tailed deer are derived from provincial objectives. The Regional objectives (B.C. Ministry of Environment 1980) are:

1. To maintain deer numbers at present day or historical levels, depending upon carrying capacity:
   i) In partially logged watersheds where mature and old-growth timber have been deferred for winter range, the objective will be to maintain deer production at levels comparable to the 1970-1980 levels; and
   ii) In the second-growth forests of productive watersheds, the objective will be to increase production from the present level of 2-5 deer per square kilometre to historic levels of 10 - 20 deer per square kilometre.
2. To maintain a minimum annual harvest of 15 000 ± 5000 deer. These objectives are based on an underlying approach of optimizing consumptive and non-consumptive use of deer.

Meeting these two objectives requires two types of action: first, to optimize deer production in second-growth; and second, to maintain the habitat necessary to sustain deer in severe winters at numbers sufficient to meet production targets.

5.2.4 Deer management activities: current, problems projected

Managing to meet stated objectives means that biologists must be able to adequately inventory the characteristics of deer habitat (food and cover aspects), monitor changes in the structure and size of deer populations over time and space, estimate the effect of predators, estimate and control

recreational use of deer, and finally, assess the effectiveness of management strategies.

At present, deer management on Vancouver Island is subjective, extensive, and largely unchanged over the last 30 years. Harvests are monitored via game checks (discontinued in 1981 due to insufficient funds) and hunter questionnaires. Control is attempted by setting season length and bag limits. Harvest data are used to supplement indices of population trend and structure because reliable, cost-effective inventory methods are unavailable.

The current goals of habitat management for deer on Vancouver Island are to preserve critical habitat and to maintain future habitat management options. Although it is not a current practice, future habitat management will be aimed at improving some existing habitat. Ideally, these goals should be met with the maintenance of sufficient habitat, of sufficient quality, to sustain the number of deer required to meet specific deer management objectives. These goals should be accompanied by a legislated mandate to manage habitat by specific population objectives, specific production goals, specific data on deer numbers and condition, specific data on range quality, and a sound and sufficient understanding of deer habitat relationships.

None of these accompaniments is present on Vancouver Island, making present habitat management basically habitat protection. This is done mostly on the basis of general principles of ungulate ecology, and some limited site knowledge and extrapolation of knowledge gained through research in a few areas such as the Nimpkish Valley and Northwest Bay.

On Crown forest lands, BCFS solicits recommendations for protection of wildlife habitat from the Wildlife Branch, though these are not necessarily implemented. Forest lands on the remaining third of the Island are controlled primarily by private forest companies and within this area wildlife managers have little or no affect.

Most of the present habitat protection for deer on Vancouver Island is directed at old-growth forests. The Habitat Management Section of the Vancouver Island Region of the B.C. Ministry of Environment regularly evaluates logging plans on Crown land for their potential impacts on deer habitat. Based on this evaluation, recommendations are made to minimize negative impacts. The major prescriptions are:

1. Protecting winter range habitat by deferring such areas from cutting, and attempting to have such areas removed from the annual allowable cut (AAC).
2. Providing planned release of areas for spring forage by issuing cutting deferrals.
3. Stipulating green-up periods for cutovers in an attempt to provide forage and cover.

In the mid 1970's, habitat protection activities for Vancouver Island deer were formalized with the preparation of "Habitat protection guidelines for ungulates" (Davies 1976). Originally, these guidelines were prepared to bring some order to what was, at that time, a rather chaotic "fire-fighting" system of habitat protection. The guidelines were based on an overall subjective assessment of what biologists knew about deer and their habitat requirements, and what they felt was necessary to sustain deer populations on all areas of Vancouver Island.

The Island was divided into habitat protection zones for which zone-specific prescriptions were developed based on the amounts of winter range, the cut rates, the green-ups, and the cutblock sizes and locations. The primary step in defining zonal boundaries was to delineate land units wherein standard prescriptions could be applied. The zonation was not, as has often been mistakenly believed, based solely on land capability to support deer. Capability was a major consideration, but the zonation also considered logging development, remaining options for maintaining deer, land tenure, recreational demand, and access. Thus the zonation was essentially subjective, and based on the idea that habitat protection measures should be applied most strongly in areas where the Ministry of Environment had the best potential to maintain deer populations, and where such populations would be used most readily. On the basis of these guidelines and some subsequent field assessments, Winter Range Plans were developed for major Tree Farm Licences on Vancouver Island. Plans for providing the necessary spring forage areas adjacent to these winter ranges are presently being prepared.

If habitat protection guidelines for old-growth forests are to become less subjective, a much improved quantitative data and knowledge base and a much more specific set of objectives regarding deer population management are required. In low elevation, second-growth systems, future habitat protection activities will likely be directed towards providing adequate cover and

forage areas for deer. Activities will be governed by the regional objective to enhance present populations of deer in second growth.

As forest management intensifies, it is most probable that wildlife management will as well. Management activities will become more and more orientated to locations where the most benefits can be derived in terms of deer produced and public recreation.

The data presented earlier (Figures 7 and 10) on capability, demand, and hunting opportunities, form a reasonable basis for deriving priority zones for deer management on Vancouver Island (Figure 11). It is highly unlikely that a significant effort will be made to either enhance or maintain high deer populations in areas of low capability and/or restricted opportunities for use (together comprising approximately 40% of Vancouver Island). Interest in such areas will likely centre on maintaining the distribution of the species. As such, significant deferrals of winter range, provision of spring forage blocks, or active attempts to enhance second-growth deer habitat are not expected.

In the other zones (Figure 11) it can be expected that intensity of activities will coincide with the designated priority (high demand/high capability combinations > high/moderate combinations > moderate/moderate combinations > high/low combinations > moderate/low combinations > low/low combinations). Winter range will not be a necessity below 300 m elevation, or feasible above 1000 m in any of the zones that historically have trends for deep snowfall accumulations (Figure 12). Provision of spring forage areas adjacent to deferred winter ranges will likely be requested in high and moderate priority zones. At present, low priority zones are questionable management zones. Further, silvicultural enhancement of second-growth deer habitat will likely be encouraged only in areas of high demand/high capability, high demand/moderate capability, or high capability/ moderate demand.

The Crown land portion of the high/high zone is expected to receive a much higher priority than the private land portion simply because the Wildlife Section has little input to forestry activities on private land. These priority ratings, however, have not been derived just on the assumption that the Wildlife Section would be the only party involved with deer management in the future. It is expected that private landowners will eventually participate in wildlife management in direct response to a large demand on the east coast of Vancouver Island for deer and other wildlife.

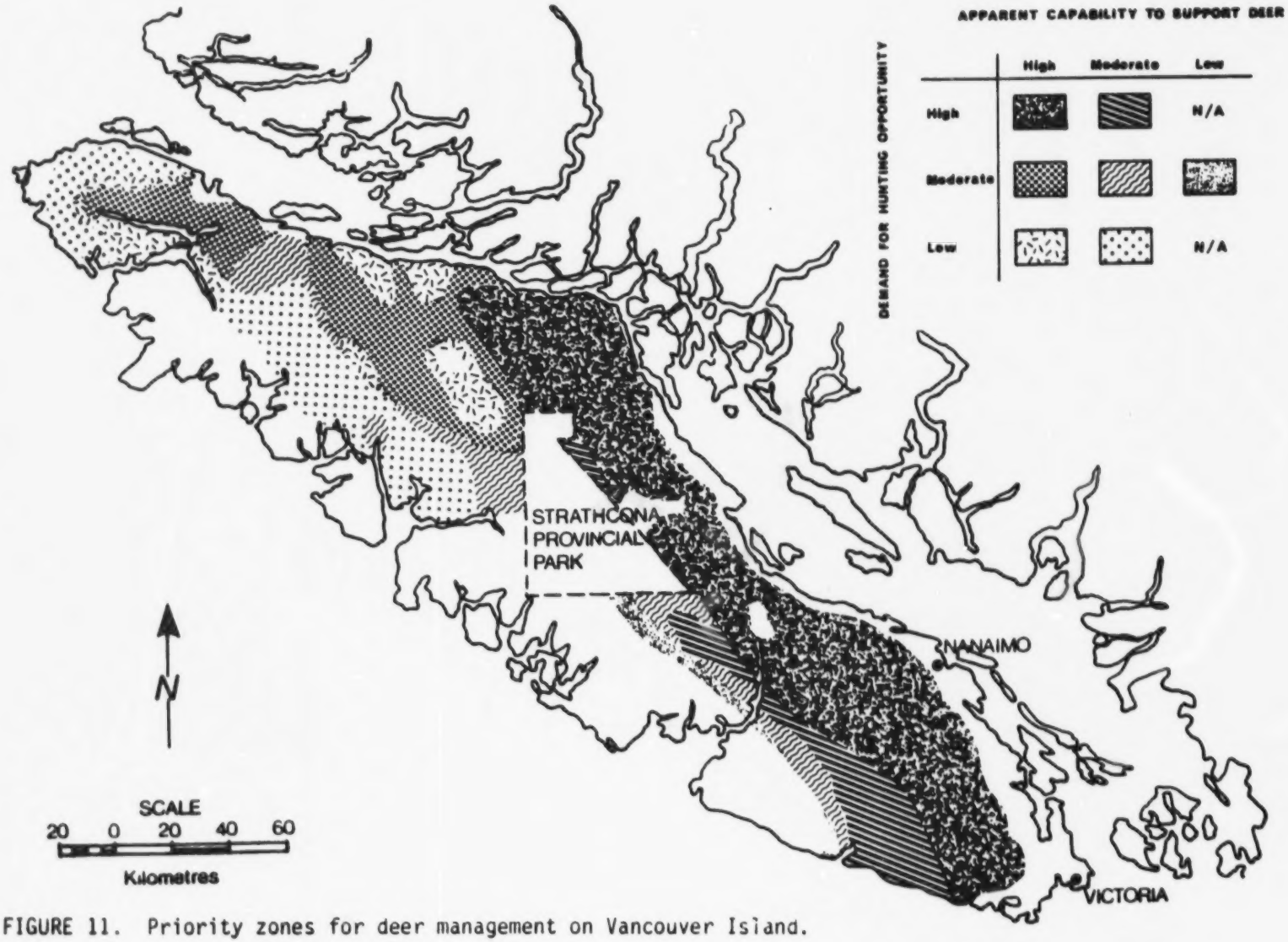

FIGURE 11. Priority zones for deer management on Vancouver Island.

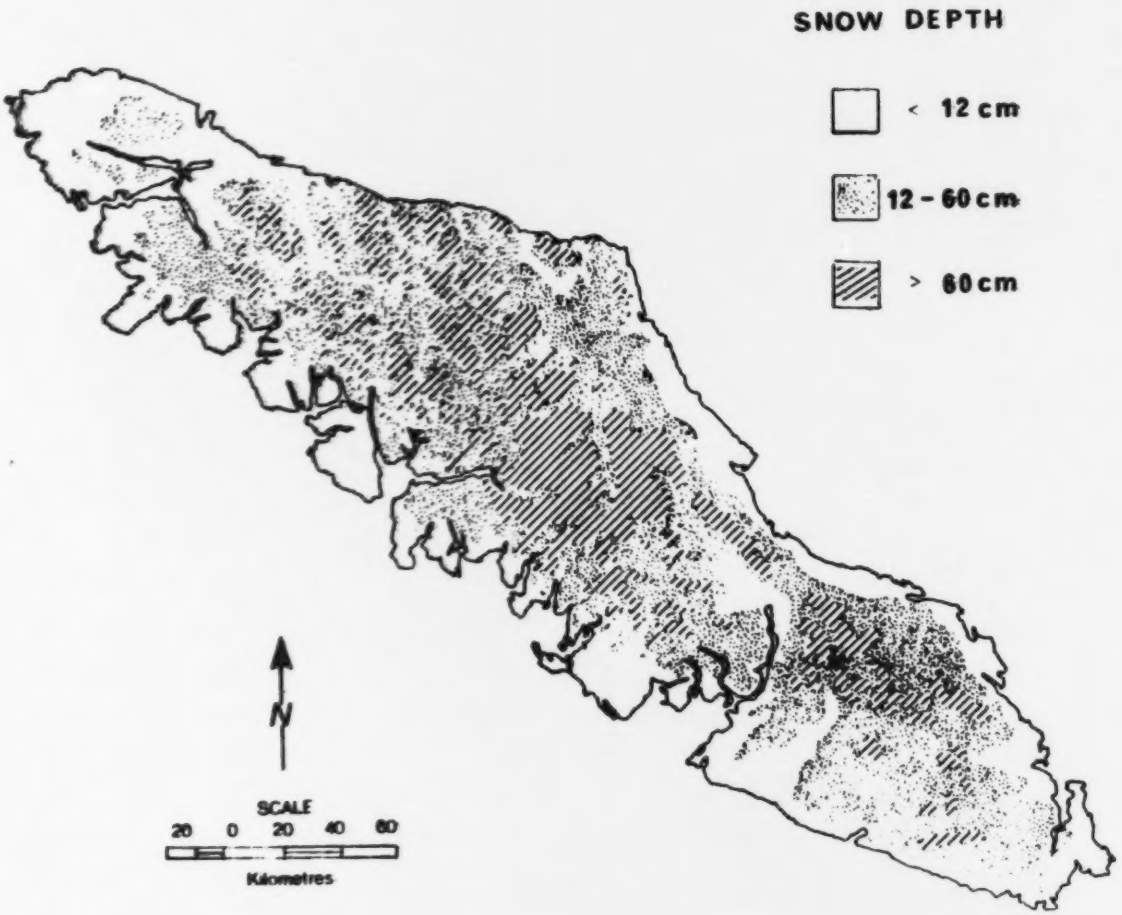

FIGURE 12. Estimated snow depth accumulation patterns on Vancouver Island.

5.3 Forest Management Context

5.3.1 Description of the resource

British Columbia has 815 000 km^2 of land base of which approximately 70% is forested land. The province itself owns 96% of this forested land, representing close to 17% of Canada's forests. With this forested land base, British Columbia controls 52% of the softwood timber volume on stocked, productive, nonreserved forest land in Canada (Bonnor 1982). The importance of the forest industry to the economy of the province cannot be mistaken, and in particular, the coastal forest region provides a substantial portion of this economy. In the 1960's, it was estimated that 33% of British Columbia's total wood volume (trees 10 in. and above at DBH), in stands of productive and accessible sites, existed in the coastal logging area. In 1973 this figure was revised to 26%.

The coast forest region is essentially coniferous. It consists principally of western redcedar and western hemlock, with Sitka spruce abundant in the north, and coastal Douglas-fir in the south. Amabilis fir and yellow cypress occur widely, and together with mountain hemlock and sub-alpine fir are common at higher altitudes. Western white pine is found in the southern parts, and western yew is scattered throughout the region (Hosie 1975). Comprehensive and current information regarding specific characteristics of the timber resource in coastal forests is difficult and time consuming to obtain.

The well-developed coastal logging industry makes a major contribution to the economic base of most coastal communities. Industrial plant capacity is such that all available timber supplies from public and private lands can be used. One-third of the timber volume goes to finished lumber while the remaining two-thirds end up as pulp products (B.C. Ministry of Environment/ Ministry of Forests 1983).

5.3.2 Goals and objectives

The general goals and objectives of the Ministry of Forests are laid down within the Forest Act (see Section 1). Objectives relating more specifically to the coastal logging can be extrapolated from Nyberg (1985).

The primary objective for intensive forest management on Vancouver Island is really a composite which stems from three sources: British Columbia Forest Products Limited (BCFP), MacMillan Bloedel Limited (MB) and the

British Columbia Forest Service (BCFS). Their objectives are taken from Nyberg (1985):

BCFP - To maximize merchantable mean annual increments by achieving culmination of mean annual increment at a mean stand diameter of 45 cm DBH.

BCFS - To manage even-aged stands for the production of sawlogs. The usual objective is to produce a stand with mean DBH of 45 cm.

MB - To maximize merchantable volume produced from even-aged stands, within the constraints of product demand forecasts (e.g. pulpwood vs. sawlogs).

These specific objectives relate only to production goals, but all are recommended under the coastal logging guidelines laid down by the Ministry of Forests in 1972 (B.C. Ministry of Forests 1972)(Section 1).

5.3.3 Forest management activities: current, problems projected

Nyberg (1985) stated that management guidelines for silvicultural activities are really only "best guesses" due to the lack of precision surrounding managed stand yield projections. Table 6 shows pre-commercial thinning standards for the large coastal Tree Farm Licenses, the BCFS, and several companies and government agencies in the U.S. Planting and commerical thinning standards are also shown for the BCFS, BCFP, and MB. The conclusion resulting from this table is that there is no single ideal silvicultural management regime.

Silvicultural regimes include more than planting and thinning. Site preparation activities (burning or scarifying) are followed by either planting or natural seeding, fertilization, weeding, clearing and crop-tree pruning. Intensive management may never occur, or could occur one or two times over the initial stages of young stand growth.

Tables 7 and 8 present basic and intensive silvicultural plans for Vancouver Island Crown land as a 5-year projection from 1 April 1982 (Brand 1981). Prescribed fire will continue to dominate mechanical site preparation. Weeding and cleaning will remain as minor activities. The dominant intensive silvicultural activity will be pre-commercial thinning, with fertilization ranking second. Conifer release programs are expected to be relatively extensive. Site rehabilitation, commercial thinning, and backlog planting are currently estimated to be small operations due to the current economic climate.

TABLE 6. Stocking standards for planting and thinning[1] (stems/ha)

Agency	Planting		Pre-commercial thinning				Commercial thinning	
			With commercial thinning		Without commercial thinning			
	Douglas-fir	Hemlock	Douglas-fir	Hemlock	Douglas-fir	Hemlock	Douglas-fir	Hemlock
B.C. Forest Service	850	1200	750	850	500	600	350	400
B.C. Forest Products	750-800	750-800	Comm. thinning not planned		600±60[2] 500±60[3] 400±60[4]	600±60[2] 500±60[3] 400±60[4]	Comm. thinning not planned	
MacMillan Bloedel	1100	1700	600-1100[5]	850-1600[5]	625	900	400-1100[5]	600-1600[5]
Crown Zellerbach (Canada)	-	-	700-800	800-1000	700-800	800-1000	-	-
Canadian Forest Products	-	-	625-800	625-800	500	500	-	-
Tahsis	-	-	625	816	-	-	-	-
Western Forest Products	-	-	-	700-775	-	625	-	-
Crown Zellerbach (U.S.)	-	-	700	850	500	600	-	-
Weyerhauser (U.S.)	-	-	740-860	1200	550	900	-	-
U.S. Forest Service	-	-	750-950	825-1050	600-750	650-825	-	-
Washington State Dept. Natural Resources	-	-	800-1000	-	600-800	-	-	-

[1] Thinning densities are residual (i.e. post-thinning) stocking levels.
[2] Good sites.
[3] Medium sites.
[4] Poor sites.
[5] Depends on stand height at which future thinning will occur.

TABLE 7. Projected 5-year averages (1982-87) for annual basic silvicultural activities on Vancouver Island (excluding private land outside Tree Farm Licenses)(from Brand 1981)

Unit	Location	Area denuded (ha)	No treatment (ha)	Area treated per year (ha)			
				Site preparation			
				Burning	Mechanical	Planting	Brushing and weeding
Quadra Timber Supply Area (TSA), Crown portion	Sayward Forest. Isolated blocks in L & M Railway Belt	679	226	141	21	453	149
Nootka TSA, Crown portion	West coast north to Brooks Peninsula	2673	1121	663	48	1552	254
Kingcome TSA, Crown portion	Cape Scott area, Quatsino Sound south to Brooks Peninsula	486	123	178	19	363	205
Tree Farm Licence (TFL) #2, Crown Zellerbach	Ladysmith, Nanaimo Courtenay, Bonanza River	NA[1]	NA	339	-	583	-
TFL #6, Western Forest Products	Quatsino Sound area	NA	NA	229	15	937	55
TFL #7, MB	Salmon River drainage	NA	NA	177	-	336	-
TFL #19, Tahsis	Nootka Sound area	NA	NA	150	50	900	57
TFL #20, MB	Clayoquot Sound area Nootka Sound	NA	NA	378	45	691	-
TFL #21, MB	Barkley Sound area	NA	NA	474	160	1909	-
TFL #22, BCFP	Port Renfrew to Nootka Sound	NA	NA	758	20	1441	234
TFL #25, Western Forest Products	Sooke, Naka Creek Port McNeill areas	NA	NA	200	-	240	5
TFL #27, BCFP	Nitinat Lake area	NA	NA	52	-	164	15
TFL #37, Canadian Forest Products	Nimpkish River drainage	NA	NA	600	40	630	20
TFL #39, MB	White, Adam, Eve, Tsitika and Benson River drainages	NA	NA	290	3	532	-
TOTALS		NA	NA	4629	421	10731	996

[1] Not available

TABLE 8. Five year intensive silvicultural program for Vancouver Island (excluding private land outside Tree Farm Licences)(from Brand 1981). See Table 7 for unit locations.

Unit	Year	Area treated per year (ha)					
		Backlog planting	Site rehabilitation	Conifer release	Juvenile spacing	Commercial thinning	Fertilization
Quadra Timber Supply Area (TSA), Crown portion	82/83	56	99	142	529	18	1152
	83/84	134	106	134	494	23	1091
	84/85	150	258	180	495	34	1723
	85/86	128	266	106	410	33	1292
	86/87	110	287	100	352	45	874
Nootka TSA, Crown portion	82/83	635	106	629	570	-	-
	83/84	210	110	650	482	10	480
	84/85	250	130	525	580	10	-
	85/86	200	180	625	533	10	-
	86/87	100	180	604	463	10	-
Kingcome TSA, Crown portion	82/83	15	15	117	128	-	8
	83/84	19	38	130	159	-	15
	84/85	58	154	125	186	-	37
	85/86	25	170	111	185	-	22
	86/87	70	184	121	183	-	22
Tree Farm Licence (TFL) #2, Crown Zellerbach	82/83	-	-	21	617	-	-
	83/84	-	-	21	612	-	-
	84/85	-	-	21	683	-	-
	85/86	-	-	36	775	-	120
	86/87	-	-	36	780	-	120
TFL #6, Western Forest Products	82/83	-	5	353	310	-	-
	83/84	-	5	481	310	-	-
	84/85	-	5	320	350	-	-
	85/86	-	5	320	395	-	-
	86/87	-	5	370	395	-	-
TFL #7, MB	82/83	-	-	150	260	-	-
	83/84	-	-	140	260	-	-
	84/85	-	-	130	260	-	-
	85/86	-	-	130	260	-	-
	86/87	-	-	130	260	-	-
TFL #19, Tahsis	82/83	100	30	200	450	-	880
	83/84	100	30	200	450	-	500
	84/85	100	30	200	460	-	300
	85/86	100	30	200	460	-	-
	86/87	100	30	200	460	-	-
TFL #20, MB	82/83	20	-	239	190	-	-
	83/84	20	-	239	190	-	-
	84/85	20	-	239	190	-	-
	85/86	20	-	239	190	-	-
	86/87	20	-	239	190	-	-

It is important to note that most activity with respect to basic and intensive silviculture is expected to take place on the east coast of Vancouver Island north of Ladysmith, as well as south of Nootka Sound on the west coast of Vancouver Island. Potential for silvicultural treatment comparisons between locations of high and low deer capability is promising (see Figure 7).

5.4 Summary of The Problem Definition

The following is a brief summary of the major points made in Sections 4 and 5.

5.4.1 Perspectives

Foresters find it difficult to accept that provision of certain types of forests for deer habitat is an important issue, especially in view of the current scale of predation by wolves.

Deer biologists have provided evidence that current logging practices are depleting winter range for deer. They predict this will cause a severe and long-lasting decline in deer populations, and remain skeptical about the potential for providing winter range in young second-growth forests.

5.4.2 Wildlife ecology context

Cover

Deer select and use habitats that approximate thermal neutrality, that help minimize sinking depths in snow, and that provide some cover from sight by potential predators. The extent to which these cover requisites are preference or requirement is unclear. The relative amounts of energy expended to achieve selection of suitable habitat is not known.

Food

The important characteristics of food are quantity available, quality (energy and nitrogen content), and digestibility. Food species selected by deer are variable and depend on region, time, and availability. Minimum levels of protein necessary for maintenance have been reported as 6-7%.

Spatial and temporal variation

How deer respond to the spatial and temporal variation of their habitat matrix (food and cover) is unclear. The problem intensifies when these variations are increased by perturbations such as fire or logging practices.

Predation

Predators can regulate and/or limit deer populations. The significance of habitat structure in prey vulnerability is unclear but has been reported as having an effect.

Behaviour

Foraging for food ranges in difficulty from most difficult in the winter, less difficult in the fall and summer, to least difficult in the spring. Learning is a large factor in determining home range selection (at least for females and non-dispersing males). Site fidelity is an important management issue. Deer show some signs of behavioural adaptation to predation, especially to predation by humans.

Population growth

At least two approaches are available for determining the quality of numbers and productivity of deer populations:

1. estimation of ecological carrying capacity; and
2. determining the net energy aquisition and expenditure on an individual animal basis.

The two assessment methods are sound theoretically but difficult to apply primarily because of inventory problems in the former, and lack of energy estimates for acitivities in the latter.

5.4.3 Wildlife management context

Cover

Thermal cover, if important on Vancouver Island, is expected to be most significant during cold, wet springs.

There are no data to indicate the significance of security cover for deer on Vancouver Island.

The need for cover from deep snow is well documented and research has progressed as far as identifying those forest characteristics most important in providing cover. Current research emphasis is on the implementation of management policies on small-scale test sites in second-growth forests.

Food

Food habit studies have been frequent and indicate that Vaccinium spp. Gaultheria shallon, Thuja plicata, Tsuga heterophylla, Pseudotsuga menziesii, Rubus ursinus, Blechnum spicant, Rubus pedatus, Epilobium angustifolium, Hypochaeris radicata, and arboreal lichens are the most important forage items.

Provision of lichens has tended to be in the centre of the resource conflict because old-growth produces far more lichens as winter forage than do young stands. Many questions have arisen concerning the use of lichens as a forage item and their management for continued availability as forage for deer.

Managers are unclear how forage availability is altered by snowpack accumulation and ablation during winter.

Spatial and temporal variation

The timing and spatial arrangement of habitat perturbations caused by forest harvesting has serious ecological implications for Vancouver Island deer populations (e.g., deer numbers may be concentrated into particular seasonal habitats; or some habitats may become entirely unavailable).

Juxtaposition of habitat types is considered to be a problem unless integrated management becomes a reality.

Managers have identified topographic and climatic gradients as important characteristics of deer habitat quality.

Predators

There are no data to determine the effect that wolves have on habitat selection by deer.

Competition

An overlap between deer and elk does occur in local situations, but there is no evidence of severe competition for resources.

Behaviour

Deer select old growth as winter habitat except where old growth has been harvested, in which case deer will use second growth. There is no information regarding differing rates of survival between deer selecting old-growth and those selecting second-growth stands. Little is known regarding predator avoidance strategies of black-tailed deer.

Population growth

The common method of assessing growth and regulation has been the evaluation of indicies of deer abundance (night spotlight counts), deer productivity (fawn/doe counts), hunter harvest data, and wolf abundance indicies.

The "net energy" approach has been used only in theory and in the form of conceptual models.

Logging activities, fluctuating weather (severe and mild winters), and increases in wolf populations have produced extremely complex and poorly understood changes in Vancouver Island deer numbers.

Limiting factors are believed to be wolves and availability of winter habitat.

The distribution of deer has not changed over recent times, but the area of greatest relative abundance has shifted from north Island to south Island.

Densities of deer can be as high as 20 per square kilometre in productive watersheds. Densities in partially cut watersheds appear highest, followed in order by uncut watersheds and advanced second-growth watersheds.

Demand

Demand for deer hunting on Vancouver Island is expected to increase in the future.

Thirty-five to fifty percent of the recreational hunting days are spent on deer (1960-1980 estimate).

Hunter success has declined from 6 to 8 days required to bag a deer in the 1960's, to 15 to 20 days required in the early 1980's.

Management

Management is largely subjective and extensive. Hunting is monitored by game checks and questionnaires and control is established by altering hunting regulations.

Currently there is no effective regional control over wolf numbers.

Habitat is managed through preservation (protection) strategies, although there is a current push for habitat improvement. Protection of winter range and spring forage areas are of primary concern.

It is unlikely that significant effort should be put into managing deer populations in areas of low capability or restricted access (40% of Vancouver Island).

5.4.4 Forest management context

In 1960, 33% of British Columbia's total wood volume, in stands of productive and accessible sites, existed in the coastal logging area.

Stands of Douglas-fir, western hemlock, and western redcedar provide the basis of a viable forest industry that is the economic base of most coastal communities in British Columbia.

One-third of the timber goes to finished lumber, while the remaining two-thirds end up as pulp products.

Most of the forest industry is committed to intensive silviculture although there is no single silvicultural management regime.

Silvicutural activities can include planting, thinning (the two most widely used), as well as burning, fertilization, weeding, cleaning, and pruning.

Most activities are concentrated on the east coast of Vancouver Island and south of Nootka Sound on the West Coast.

5.4.5 The problem summarized

There appear to be two basic concerns over the management of the deer resource on Vancouver Island, only one of which is directly related to intensive forest management. The short-term, but pronounced, effect of predation on deer by wolves is a management problem of concern to the Ministry of Environment. The longer-term, but perhaps most serious, problem originates from the following conflict in objectives between the ministries of Forests and Environment: Intensive forest management has the potential to cause large-scale changes to deer habitat. Wildlife managers have limited input to where and when the large-scale changes occur. Deer winter ranges are thought to be the current (but long-term) limiting factor to deer population levels, and hence old-growth winter range availability has been the focus of the conflict, although it is by no means the whole conflict.

The general problem is a lack of integrated and co-ordinated management of a resource that is basic to both the forest industry and to black-tailed deer. There are a number of reasons for this:

1. There is a difference in perspective associated with this resource conflict (Section 5.4.1) and this divergence results in the inability to percieve and plan for specific management activities (both on the side of forest managers and wildlife managers).

2. There is an inadequate understanding of how deer respond to changes in the cover characteristics (thermal, security, and cover from snow) of their habitats, imposed by intensive forest management.
3. Food availability and quality is expected to change due to intensive forest management. This problem is reviewed in greater detail by Nyberg (1985).
4. It is not well understood how deer respond to changes in the juxtaposition of habitat types imposed by intensive forest management, or how altering the ratio of cover to food affects deer.
5. Because of points (2)-(4), there is an inability to recommend second-growth silvicultural practices that would enhance deer production to meet the demand for deer.
6. There is no information regarding the effect of wolves on habitat selection by deer.
7. Individual behaviour of deer is expected to have an influence on the success of habitat management attempts.
8. There is an inability to inventory deer populations, deer harvests, and deer habitat at desired scales and with desired accuracy so that points (2)-(4) can be monitored and point (5) assessed.
   Although energy values for deer forage have been obtained and energy cost of locomotion through snow has been estimated, much scientific research is necessary before precise estimates of net energy can be used as a means of assessing point (5).
9. There is a lack of area-specific management for deer comparable to the site-specific management of forests.
10. There is an inadequate legislative base to force the modification of land use activities and so manage deer and their habitat.
11. There is a lack of incentive for forest managers to become involved in deer habitat management. That involvement would effectively reduce current levels of timber production and hamper attempts at changing production goals to parallel market fluctuations.

6 INFORMATION NEEDS

The principle problem facing managers is their inability to predict adequately the effects of intensive silviculture on deer populations.

Subsequently, few recommendations can be made for effective integrated forest-wildlife management. This problem is primarily due to an inadequate understanding of how deer respond to the habitats created by forest management activities and regimes, as individuals and as populations. Managers can make general predictions about deer population responses, but only gross changes are detectable with current inventory methods and resources (Harestad and Jones 1981). Thus the manager's problem is predicting both the vegetation or habitat response to silviculture and the deer population response to the changes in habitat, within confidence limits appropriate to management objectives.

6.1 Needs Identified by Defining the Problem

Integrated management can take place only after such time as differences in perspectives have been resolved and policy statements on production objectives have been produced. Forest managers have production objectives firmly in place (e.g., annual allowable cut) but wildlife managers must be explicit, site specific, and more quantitative in stating production goals. In the interim, until recreational objectives are set, there must be a relay of information from research personnel to forestry and wildlife management. Information should be in the form of a simple and concise handbook that explains why habitat is important to deer and how various aspects of a deer's life requisites are linked to habitat. Furthermore, the handbook should describe how silvicultural prescriptions can alter deer habitat. One significant lack of information remains that concerning absolute numbers of deer. Wildlife managers are encouraged to use their "best indices" in the meantime so that integrated management can be viewed as a viable solution to the current resource conflict.

6.1.1. Habitat: physical environment parameters

Cover

An understanding of how deer respond to "effective temperature" (radiation, wind, relative humidity) gradients is required to define exactly what a deer's thermal cover requirements are. We assume thermal cover to be important to the deer for conserving energy. Thus, if less heat is lost to the environment, then more energy will be available for other purposes such as locomotion and reproduction. To evaluate habitat suitability in serving as thermal cover, managers require information

about the effect of vegetation on factors affecting heat loss, such as temperature and windspeed. It is important that information concerning deer response to these factors be recorded, since deer can respond both physiologically and behaviourally (Section 5.1.4).

Hatter (1982) indicated that information is needed regarding the effect of intensive silviculture on prey vulnerability to predators. Do isolated blocks of mature timber concentrate deer and increase their vulnerability? How can the important physical characteristics of hiding and escape cover be identified, measured, and therefore incorporated into silvicultural practices?

Cover from deep snow in winter is influenced by the way in which forest canopies intercept and redistribute snow (Bunnell et al. 1985). The characteristics that most old-growth winter ranges have in common are well documented (Bunnell 1985). Manipulative research based upon current understanding of forest/snow interactions (Bunnell et al. 1985) should improve our knowledge of critical components of winter range and of how deer react to such habitat management. Such experiments will also determine our ability to silviculturally manipulate second-growth stands with silviculture, and so mimic old-growth conditions (Nyberg et al. 1985b).

Nutrients

Defining the forage resource, quantifying its abundance and quality, and determining how deer respond to changes in forage resources are complex problems. "Forage" includes a large, diverse collection of plant items differing in temporal and spatial distribution and abundance and in chemical composition, size, and form. Vegetation varies in biomass, species composition, and productivity relative to environmental site factors, disturbance, and time.

The most relevant variables to consider for forage species are biomass, current annual growth, cell structural components and cell solubles, digestibility, nitrogen, energy content, and secondary compounds.

The patterns and processes of secondary vegetation succession (either naturally or silviculturally induced) can differ greatly as a function of site factors and predisturbance community structure. The quality of the resultant habitat varies accordingly. Thus, we require quantification of succession vegetation dynamics before we can relate

deer responses to any changes in forage. The effects of silvicultural practices on understory vegetation dynamics needs to be understood generally, in terms of the rate and pathways of secondary succession, and specifically in terms of species composition, biomass, and annual productivity.

Vegetation in both climax and successional plant communities has been studied extensively on Vancouver Island (for a review see Krajina 1965; Packee 1972; Klinka 1976; Nyberg 1985), but it is a complex and difficult endeavour that requires much more intensive work. Ellis (1980) recommended initiation of a major research program on Vancouver Island, involving growth and yield parameters of forest stands and the autecology of understory species. The effects of major silvicultural practices should be stressed in such studies. None of the past studies (Cowan 1945; Gates 1968; Harestad 1979; Rochelle 1980) provide any data on silviculture effects on forage production.

The importance of lichens as winter forage has been documented (see Section 5.2.1.2). Digestibility, nutrient content, and availability of lichens for deer have not been fully evaluated. In addition, the biology of lichens should be investigated to provide knowledge on their management as deer forage. Such investigations should include: dispersal distance of seed sources, growth rates of lichens, growth substrate requirements, litterfall rates, and standing crop inventory techniques (Stevenson 1978).

As well as increasing locomotory costs to deer, snow also limits forage availability. The relationships among snow depth, burial, compression, horizontal and vertical distribution of forage, and resultant forage availability and quality have been investigated to some extent in the Nimpkish Valley (Harestad 1979), but many of the relationships have been developed empirically and need extensive field testing (see Harestad and Bunnell 1979).

Spatial and temporal patterns

Managers must consider the characteristics of adjacent stands when providing management proposals. For example, where winter ranges are deemed to be necessary, the questions that should be asked are: How much? Where or what should be the spatial orientation of distribution of such habitat? Will winter range reserves turn out to be predatory traps? The general nature of topography-snowpack relationships and

likely correlation with deer range use are fairly well understood, but current inventory data on regional and local snowfall are lacking for much of Vancouver Island, thus hampering management predictions for winter range on the basis of snowpacks. An up-to-date version of Figure 12 is necessary to delineate priority zones for winter range management.

Orientation of spring forage range and winter range is a topic concerning most deer managers. Managers wish to provide forage areas that will be readily accessible in early spring to deer using adjacent winter ranges. It is not known at what distance from a winter range spring forage will become "inaccessible" due to home range size constraints. Snow conditions fluctuate over time and space, and thus managers need to understand how these changes affect travel costs and, most importantly, habitat selection.

Wallmo and Schoen (1980) suggested that old growth forests have a more variable spatial orientation of both forage and snow than other habitats. Old growth could potentially enable reduced locomotion cost and higher amounts of more nutritious forage than other habitats with the comparable "mean" snow depths but less variable accumulation of snow. This topic is currently under preliminary investigation (Bunnell 1984; Nyberg 1985).

Spatial orientation of forage areas to security cover is another area where information is needed. No current research has been planned.

Integration with the Habitat Management Section of B.C. Ministry of Environment will be required when habitat juxtaposition problems are addressed.

6.1.2 Predation and competition

Hatter (1982) outlined 11 questions that need to be addressed to increase understanding of predator-ungulate relationships on Vancouver Island. Most questions focus upon the influence of wolves on deer recruitment, survival, and habitat selection, and upon the potential for snow and silvicultural practices to alter predator impact. What habitat type is required to limit the functional response of predators? How can forest characteristics be measured and incorporated into silvicultural practices?

More information is required to enable integration of wolf management into ungulate-habitat systems. Currently this management entails the reduction of wolf numbers. Longer-term objectives should be to explore the potential of using habitat management to create greater security cover for deer, and to document the level at which Vancouver Island wolf and deer numbers can reach equilibrium. Specific needs are to understand how wolves influence habitat selection, how cutblocks are used seasonally and nocturnally by deer, and what the physical characteristics are of security cover (Hatter 1982).

6.1.3 Behaviour/adaptive strategies: habitat selection

The important question regarding habitat selection is how does a deer respond to its environment and use habitat while meeting its requirements? Answers to this question are necessary for assessment of relative value of habitat components to deer and/or habitat quality.

Many of the major deer-forestry management conflicts revolve around why deer use or select particular habitats. A limitation of investigating habitat selection, however, is that it can only indicate the deer's choice of the available alternatives, but will not necessarily indicate what is the "best" habitat if the latter is unavailable. A similar problem revolves around the issue concerning selection, preference, and requirement. Information is required that will help to resolve the problem of differentiating between what is a preferred habitat and what is required for survival. Thus, in addition to habitat selection data, we need to be able to assess what benefit a deer gains by selecting a particular habitat.

In the high snowfall areas we do not fully understand the functional differences between critical and average winter range. We will need a much greater understanding of the spatial aspects of home range-related behaviour to answer these questions. Current studies using 19 radio-collared deer on Vancouver Island reveal great variation in home range and habitat selection pattern. We also need to know why deer winter in poor ranges when 0.5 km down a valley, snow conditions may be much less severe and ranges adequate. Do deer get trapped on these upper ranges by increasing snow depths during the winter? To what degree does learning enter into habitat selection? Home range fidelity during winter and deer movement in response to snow conditions need more study.

6.1.4 Population growth and regulation

In recent times the economy has endangered the continuity of collecting baseline population trend data. Population reproduction parameters and fawn/doe ratios are currently the only viable techniques that can be used for population productivity estimates and the importance of their continued use needs to be stressed.

The "net energy gain/loss" technique is useful potentially for improving our conceptual understanding and providing "best guesses" for field level management (Potvin and Hout 1983; Section 5.4.2). However, few, if any, researchers have been able to extrapolate "net energy" theory to field management situations. The use of energy as a fundamental measure of population productivity for decision-making in wildlife management is recent (Moen 1973). Generally, knowledge is required that will help make "net energy" theory more applicable for field level management.

The determination of energy and protein requirements for an animal is a costly, difficult, and time-consuming process. It consists of measuring physiological responses at varying nutritional and/or activity levels, and assessing such parameters as survival, weight changes, condition, and reproductive performance. Research involving domestic ungulates has been substantial, lab research on wild ungulates less common, and actual field trials on wild ungulates very rare. Refinement for estimates of these costs will require considerable field research with wild ungulates (activity costs and physiological response); much more data on seasonal and daily activity regimes; and, most importantly, the testing of deer population response to range condition, based on predictive estimates or models of protein/energy needs.

6.2 Needs Identified by the Modelling Approach

Using a modelling approach to understanding the system of deer/intensive forestry interactions has several advantages (Martin 1968):

1. Decisions concerning the future system can be made while the system is still in a conceptual stage.
2. System performance can be simulated and observed under all conceivable conditions (real world and/or hypothetical situations).
3. Results of field system performance can be extrapolated on simulation models for purposes of prediction and hypothesis generation.

4. System trials are speeded up and more cost efficient.

The following four models of deer/intensive forestry interactions are discussed:

Conceptual models - 1) energy functions (Harestad et al. 1982) and
2) optimal foraging theory (Hanley 1981); and

Descriptive simulation models - 3) ESSA (McNamee et al. 1981) and
4) STUF (Shank and Bunnell 1982c).

Conceptual models

Harestad et al. (1982) presented a simple conceptual model comparing two energy functions during winter: 1) the relationship between energy (food) availability and snow depth, and 2) the relationship between energy expenditure for movement and snow depth (Figure 13a). The model implies that under shallow snow conditions deer acquire a net benefit because more energy is acquired than expended. The converse is true in deep snow. Contrary to the model, a net energy gain may be possible for deer during spring and summer seasons, but is unlikely during winter for either forage availability or behavioural reasons (Bandy et al. 1970; Nordan et al. 1970; Section 5.1.4). Therefore, the model presented by Harestad et al. (1982) may have more utility for seasons other than winter, and with a locomotion impediment such as logging debris.

Figure 13b depicts the same conceptual model for a winter season, with corrections made for behavioural changes (reduction of forage intake and BMR, and the catabolism of body tissue). This model expresses energy expenditure without consideration of distance travelled and trailing behaviour. Home range studies indicate this distance is usually lower in winter than in other seasons. The energy expenditure function in Figure 13 is well documented by Parker et al. (1984). Very little information is available concerning the energy acquisition function.

Figure 13b implicitly points out that deer select habitats with minimal snow accumulation. Because the net energy is slightly negative during winter, the best habitat for deer must be one that will allow minimum energy deficit. The primary question is whether or not deer select habitat on a "threshold" basis or whether deer respond to snow conditions on a simple energy cost model? Regarding the latter, this may not be the case since deer often remain as high as possible in snow areas and do not appear to be selecting the most snow-free areas or

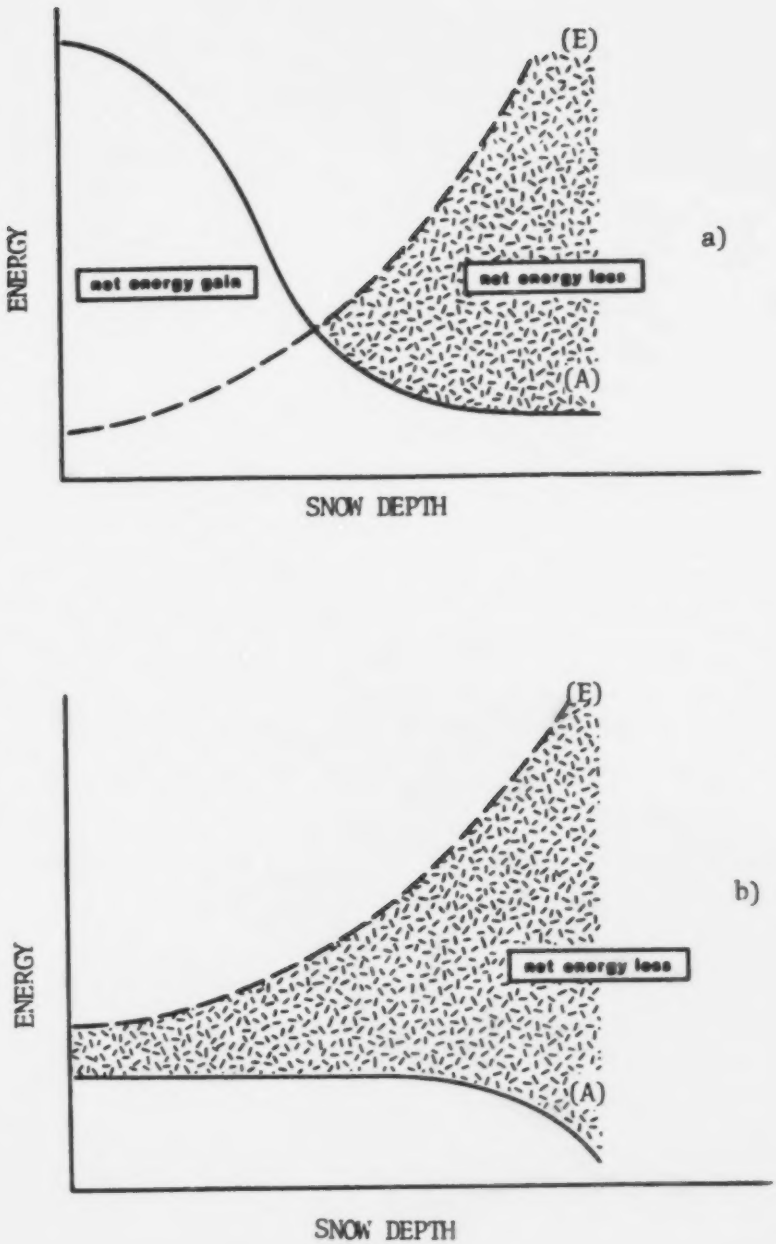

FIGURE 13. A conceptual model of the influences of snow depth upon energy expenditure (E) and energy acquistion (A) for a wintering deer: a) from Harestad et al. (1982), and b) altered to consider characteristic winter behavior and winter net energy balance.

least snow depths. The models in Figure 13 express energy gains and expenditure in relation only to snow depth, but similar models could be designed for other seasons and other energy costs/benefits.

The second conceptual model of deer and intensive forestry interactions is more specific to habitat selection based on optimal foraging theory (OFT) (Hanley 1981). OFT is based on the premise that deer will harvest food efficiently and that they will choose the most profitable foods relative to the choices available. Further, it is assumed that deer will change feeding areas only when they can do better (i.e., obtain higher intake) by travelling to another habitat. Thus, according to OFT, the optimal allocation of time to a habitat is that which maximizes net rate of nutrient intake. OFT, exemplified by Hanley's (1981) model of habitat selection and habitat quality, proposes that deer "optimize" and that most aspects of habitat selection can be explained on the basis of foraging theory (Figure 14). This theory suggests that deer only have to move to eat, making foraging the major consideration. Hanley indicates that during winter deer can only last a short time without food, and thus foraging is the driving force behind habitat selection and the best basis for assessing habitat quality. He assumes that optimal allocation of time or the maximizing of net rate of intake is synonymous with habitat quality, and that observed habitat selection (because it is based on time) reflects habitat quality. He further emphasizes that one must consider both food consumption and food processing when discussing foraging efficiency because diet quality determines not only the energy intake per unit time feeding, but also how much time can be spent feeding each day. Thus Hanley reduces the problem of habitat quality and habitat selection (deer's food acquisition strategies) to a problem of the deer choosing the combination of diet and habitat (foraging availability) that will maximize its foraging efficiency:

- Foraging efficiency is a function of diet and amount consumed.
- Amount of forage available for consumption is a function of the habitat selected.
- Foraging costs are a function of the habitat selected and the amount of time feeding (latter partially a function of diet).

Despite the emphasis on diet, habitat quality can be assessed on the basis of an intake function (such as net energy) and a cost

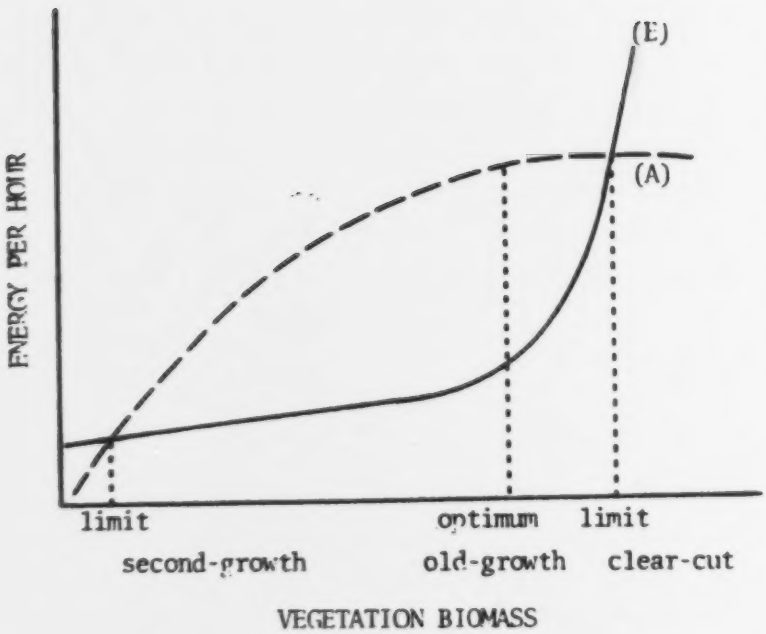

FIGURE 14. A conceptual model of habitat selection based upon vegetation biomass where energy expenditure (E) and energy acquisition (A) are hourly energy functions (from Hanley 1981).

function -- habitat quality being the difference between the two functions. Changes in forage availability and quality will change the acquisition function, while changes in environmental costs such as thermal environment or locomotion difficulties in snow will change the expenditure function. Some factors such as snow, which bury forage and increase travel costs, will change both functions.

Both conceptual models ignore predation or the possible need for cover, both of which may influence use of a feeding area. Further, both models assume that non-foraging activities and use of habitat for same, are not very important in assessing habitat quality and habitat selection. The models assume that any time a deer uses a habitat, it is attempting to maximize net gain (Hanley's model) or minimize net loss (Figure 13). Do deer always optimize? Can habitat quality and observed habitat selection be evaluated on this basis? At present, we simply do not have sufficient deer movement or habitat use data to evaluate these theories.

Descriptive models

Two models that attempt to clarify conceptual understanding of black-tailed deer/intensive forest management interactions by the simulation approach are the ESSA and STUF models.

The first model was formulated in 1981 through a workshop approach (McNamee et al. 1981), the objectives of which were to:

1. develop a framework for co-operation and communication between wildlife and forestry interests;
2. develop a conceptual framework, in the form of a computer simulation model, to use as a guide in developing a research plan for IWIFR;
3. develop a set of hypotheses about important processes in the system under study;
4. develop a framework for testing hypotheses, and provide a basis for evaluating the relative importance of different processes; and
5. resolve the question of the level of detail for research in the program.

Elk, deer and their predators are the only wildlife species considered.

The second model took form at the University of British Columbia (UBC) (Shank and Bunnell 1982c). It was named STUF to reflect the focus on snow, trees, ungulates, and forage, this model was developed to:

1. guide research directions concerning deer/intensive forestry interactions, and providing a dynamic synthesis of research results;
2. identify relevant processes in the system under consideration;
3. create an understanding of sectors of strength and weaknesses in the system leading to a sharper conceptual image of the perceived interactions; and
4. develop a sense of which processes and parameters might be most important.

The model explicitly ignores predator influence in the system and considers only deer.

The following discussion attempts to answer five questions concerning results of the two modelling efforts:

1. Is the model sufficiently simple that the basic concepts presented are understood?
2. Do the logical assumptions introduce potential confounding and/or unreliable synthesis?
3. Are the important issues of the system (based on current knowledge) all incorporated?
4. What questions are raised by the model? Where is knowledge lacking?
5. Can we extract the relative significance of each problem issue in the system?

Producing these general models necessitates decisions concerning choices of specific subroutines. For some particular subroutines, many modelling choices already exist in the current literature.

6.2.1 The ESSA deer submodel

The ESSA deer submodel presents a hypothetical situation in which a watershed is divided into one hundred 80-ha blocks. The deer submodel loops over three seasons and deer are assigned to habitat "blocks" on a relative basis according to the value of the particular "block habitat." The value of each "block habitat" depends upon winter range value, escape cover value, and food value, which are all variable characteristics of each block. Sections 2.2 and 2.6 of the McNamee et al. (1981) report clarified the particular parameters involved and the interaction matrix for the modelling exercise.

Because the ESSA model was created with the intent of developing a research plan for IWIFR, it is therefore directly related to research concerning deer/intensive forestry interactions. Research recommendations resulting from the exercise include hypotheses concerning:

Snow

- the effect of snowfall frequency on food supply and energy costs.
- the effect of tree canopy characteristics on snow interception.
- the relationship between snow depth and food availability.

Movement

- the selection of winter habitat as guided by fidelity and snowfall patterns.
- the components relating to value of a site as deer habitat and subsequent description of the utility of the site as winter range escape cover, and foraging habitat.
- the seasonal range size of a deer.

Foraging

- the preference that deer have for various food types.
- intra-specific competition for food resources.

Survival and reproduction

- winter mortality as the only other source of mortality besides hunting and predation,
- the influence of winter and spring energy intake on reproduction.
- the compensatory and/or additive natures of winter mortality and predation mortality.

While the ESSA model incorporates all of the issues concerning deer/intensive forest management interactions, it does so at the expense of being vague and unreliable. The unreliability stems primarily from the numerous and confounding assumptions that are used. Weighting factors employed with limited empirical knowledge create many basic assumptions (e.g. security cover indicies, restrictions on seasonal movement patterns, searching efficiency ratios). Assumptions and "guesses" end up as concurrent tests in the model.

No confidence can be placed in judging the relative significance of information needs even though the information needs are clearly represented in the ESSA model. Perhaps the most effective use of the ESSA model are its assumptions. Many of the these (represented by the list of research recommendations made earlier) require further baseline field knowledge so

that less complex subroutines could be run. The intent would be to formulate prediction hypotheses from each subroutine to guide specific research projects.

6.2.2 The UBC STUF model

The simulation model STUF consists of three major submodels: 1) a snowpack subprogram, 2) a subprogram describing forage availability and use, and 3) a subprogram describing energy costs of deer locomotion through snow. The current emphasis on refining the model is to improve the realism of the snow submodel.

The time period for the model is 1 day and is restricted primarily to the winter and spring seasons. The model is not site-specific but operates on point estimates that exhibit various site factors such as canopy cover, slope, aspect, and elevation. A complete interaction matrix is given in Table 1 of Shank and Bunnell (1982c). The major differences between STUF and the ESSA deer submodel are that:

1. the time step is 1 day as opposed to one season;
2. the spatial cell is 20 m on a side rather than 80 ha in area;
3. the deer are allowed to move from one cell to another without time constraints;
4. model refinement is an ongoing procedure as data become available to evaluate and test model assumptions.

Currently, only the snow subprogram operates with sufficient predictive capabilities to be tested. Information needs identified by model operation thus far are:

- daily measurements are needed (instead of monthly or weekly) before refinement of the snow melt subroutines can take place.
- management for uniform, intermediate canopy covers may encourage uniform destruction of the forage throughout winter and early spring under extreme conditions.
- reasonable values for the interaction between distance moved and energy expended by deer.
- "real world" canopy cover - forage biomass relationships.
- development of more sophisticated decision-functions for deer choice of feeding areas.

- small-scale spatial variability patterns.

STUF does not incorporate all the issues concerning deer/intensive forest management interaction nor is it a finished product. However, it is a simple model that is conceptually clear. Its assumptions are explicit and conform to the data driving the model. Unvalidated assumptions are not incorporated but are identified as information needs instead.

6.3 Summary of Information Needs

This section provides a short list of study topics that could lead to better evaluations and definitions of how intensive forest management affects the selection and use of habitats by deer. Some of these topics are listed below even though they may replicate the results of Hatter (1982), Nyberg (1985), and Nyberg et al. (1985b). Emphasis, however is placed on topics concerning only deer response to habitat and habitat conditions. At the same time, it must be emphasized that there is a need to clarify the relative importance of predation by wolves and humans and of habitat (primarily winter range) to deer populations and their management on Vancouver Island.

Habitat characteristics

1. We need to test both our abilities to manage second-growth stands to produce winter range conditions for deer, and to test our models of snow interception by forest canopies. This is a logical progression of Priority 1 of Nyberg (1985). These tests will also help demonstrate and transfer knowledge to foresters.
2. We need to quantify succession vegetation dynamics and to provide realistic canopy cover-forage biomass relationships. The relationships would provide a scale on which to evaluate deer response to forage changes imposed by silvicultural practices. This is stated as Priority 2 of Nyberg (1985) and is currently being undertaken by the IWIFR program as well as at UBC.
3. We need to find a means of managing lichens as a key winter forage item that might not otherwise be produced in second-growth winter ranges. Nyberg (1985) noted this in Priority 1. This need is currently undergoing a problem analysis (Stevenson 1985).
4. We need to quantify the change in availability of winter forage items as snowpacks accumulate and ablate. This need is stated in Nyberg (1985), Priority 1, and is currently being undertaken in the IWIFR program as

well as at UBC. The purpose is to improve predictions on forage availability during winter.

5. We need to quantify the physical characteristics of security cover in different habitats (Hatter 1982). This is also Priority 3 of Nyberg (1985). Nyberg (1985) alluded to the fact that the need for such cover should be determined before emphasis is placed on studying how intensive forest management altered security cover.
6. We need to quantify how forest variables modify "effective temperature" gradients in forest stands. This is Priority 4 of Nyberg (1985). Determining the response of deer to "effective temperature" should probably take place prior to studying the influence of forest variables on "effective temperature".
7. We need to know the integrated effects of climate, topography, and vegetation as they relate to snowfall patterns and conditions on Vancouver Island. This need was not identified as such by Nyberg (1985), but it would help determine winter range management regions and priorities for winter range management on Vancouver Island.

Responses of deer to habitat and habitat conditions

1. Habitat suitability model: We need a short, simple document that describes how habitat components satisfy the various life requisites of deer. Wildlife managers would be required to make evaluations of optimum habitat carrying capacity and to express relationships in terms and expressions regularly used by foresters. The document would help relieve the perspective divergence between foresters and wildlife managers and to provide a basis for integrated management (see "Perspectives", Section 5.4.1).
2. Thermal cover: We need to quantify how deer respond to "effective temperature" gradients. The purpose is to identify conditions that may present thermal stress and extreme losses of energy for deer (see point (6) above and "Thermal cover", Section 6.2).
3. Security cover: We need to document how deer respond to the elimination or severe alteration of security cover, to determine if security cover is a requisite of deer, and if further study is required to define the characteristics of security cover (see point (5) above and "Security cover", Section 5.4.2).
4. Locomotion in snow: We need to clarify the effects of snow characteristics on sinking depths of black-tailed deer and further, we

need reasonable values of the interaction between distance moved and energy expended by deer. The purpose is to enable extrapolation of the findings of Parker et al. (1984) to the situation in coastal British Columbia and, further, to map energy expenditure functions into existing models of habitat quality that are based on "net energy balances" (see Section 6.2).

5. Juxtaposition of habitat types: We need to study deer response to varying juxtapositions of habitat types. Particular emphasis should be placed on: i) proximity of spring forage to winter ranges; and ii) the number and position of winter ranges in watersheds. The purpose of such study is to allow more area-specific (e.g. watershed level) management plans (see "Spatial and temporal variation", Sections 5.4.2 and 5.4.3).
6. Predator influence: We require information that will help our understanding of the influence that wolves impose on habitat selection and use by deer. The purpose is to help to determine the relationships between wolves, deer, and habitat selection by deer, and further, to evaluate these relationships in varying conditions of security cover (see Section 5.4.2).
7. Site fidelity: We require information concerning the response of deer to our attempts at managing second-growth forests for winter range. The purpose is to determine the significance of site fidelity and other behavioural issues thought to affect the use of managed winter ranges by deer (see Sections 5.4.2 and 5.4.3).
8. Decision functions: We require seasonal decision functions for a deer's choice of habitat types (feeding and cover); and an estimate of probability of survival parallel to the decision functions. Eventually, we will need to understand decisions made at a finer level of detail (e.g. forage selection, micro-habitat selection).
9. Distance of movement: We need documentation of seasonal range sizes and seasonal linear travel for deer so that this information can be mapped into seasonal energy expenditure functions (see Section 6.2).
10. Winter-spring energy acquisition and expenditure: We require information concerning the influence of winter and spring energy intake and expenditures on reproductive success of deer. This information as well would be mapped into energy-based models of habitat assessment.
11. Simulation modelling: We need to collate existing habitat selection, energy acquisition, and energy expenditure data for deer, and to model

(as simply as possible) the interaction of the life requisites of deer. The purpose of the modelling exercise is to provide an estimate of the relative importance of each of the life requisites for deer and to integrate findings from points (2)-(6) and (8)-(10) above (response of deer to habitat and habitat conditions). The results would enable more confidence in defining where research priorities should be placed in the future and would add support to point (1) above.

7 RESEARCH TOPICS

7.1 Setting Research Priorities

Within the following discussion, information needs are assigned priorities. The 11 topics on deer response to habitat and habitat conditions (Section 6.3) were ranked according to their individual importance, using 16 criteria (Table 9). Each information need (henceforth called a potential research topic, Table 10) was given a simple rank (high, medium, or low) for each specific consideration (Table 11). The first seven criteria were used to identify the relevance of a particular research topic to IWIFR's mandate. A joint report from the ministries of Environment and Forests (B.C. Ministry of Environment and Ministry of Forests 1983) and Section 6.3 of this report indicate that most topics have a high ranking for at least these first seven criteria and therefore only the last nine were assigned points (High=3, Medium=2, and Low=1). Priority was based upon point totals. The result was that the potential research topics identified in Section 6.3 could be listed in order of priority (Table 12).

Aside from the priority ranking system described in Table 10 and used to generate Tables 11 and 12, there must be some thought given to how the various research topics relate to each other. Topics 4 and 10 rank evenly in Table 12, but their relation to each other dictates a difference in priority. Available data bases have yet to be fully explored concerning: 1) deer locomotion in snow (work in progress at UBC) and 2) availability of forage during winter and spring (work in progress at UBC and the habitat component of IWIFR). It would be logical to pursue these issues before putting much emphasis on topic 10 - winter and spring energy acquisition and expenditure functions, and their relation to the reproduction success of deer.

To continue the above "critical path" approach, it would seem logical to know how deer proportion their time in individual habitats before topic 10 is

TABLE 9. Criteria used to assess priority of information needs

Is the topic within the realm of the organization?
1) Legislative responsibilities
2) Agency priorities and policy
3) Public concern
Is the topic of major concern to the organization?
4) Extent of the problem location, region
5) Timber values involved
6) Wildlife values involved
7) Timber and wildlife production opportunities
Are there current management actions available to the solve the problem?
8) Is new information essential?
9) Consequences of no research
10) Attitudes and social systems (i.e. management "climate")
11) Need for demonstrations and technical transfer plan
12) Are there models available to generate effective research?
What are the cost-benefit details?
13) Cost of research
14) Probability of success and risk
15) Independence of the results from research: can they be implemented?
16) Timeframe of the research activities and benefits

TABLE 10. Short title list for the potential research topics identified from "information needs"

Responses of deer to habitat conditions and components

1. Habitat suitability model
2. Thermal cover
3. Security cover
4. Locomotion in snow
5. Juxtaposition of habitat types
6. Predator influence
7. Site fidelity
8. Decision functions
9. Distance of movement
10. Winter-spring energy acquisition and expenditure
11. Simulation modelling

TABLE 11. Ranking of potential research topics (from Table 10)

Criteria consideration	Research topic[1]							
	3	4	5	6	7	8	10	11
Is the topic within realm of organization?								
Legislative responsibility	H[2]	H	H	M	H	H	H	H
Agency priority	H	H	H	L	M	H	M	H
Public concern	H	H	M	H	M	H	M	H
Is the topic of major concern to the organization?								
Extent of problem location	H	M	H	H	H	H	H	M
Timber value	?	H	H	?	?	H	?	H
Wildlife value	H	H	H	H	H	H	H	H
Timber and wildlife production	H	H	H	H	H	H	H	H
Are there current management actions available?								
Minimal information required	L	M	L	L	M	H	M	M
Implications of no research	L	M	H	M	M	M	M	M
Management "climate"	L	M	H	L	M	M	M	M
Minimal technical transfer	M	M	M	M	M	L	M	L
Model availability	H	H	L	M	M	M	M	M
What are the cost benefit details?								
Low cost of research	L	H	L	L	M	H	H	M
Probability of success	M	L	M	M	H	M	M	M
Independent results	M	M	M	M	M	M	M	L
Short term time frame	M	H	L	M	M	M	H	L

[1] Research topics are identified by short title in Table 10.

[2] Ranks are H=high, M=medium, and L=low.

TABLE 12. A priority listing of topics for research on black-tailed deer and intensive forestry interactions

Priority ranking[1]	Project No.[2]	Re-ranked[3]
1	1,2,9	1,2,9
2	4,10	8
3	7,8	4
4	5	10
5	3,11,6	7
		5
		3,11
		6

1 Overall priority is based upon totals accumulated for each project, where points of priority (High = 3, Medium = 2 and Low = 1) were assigned to each of the 16 criteria considered for every project (see Table 11).

2 For project short titles see Table 10.

3 Re-ranking occurred to make projects fit a more logical flow of information gathering (refer to the discussion in Section 7.1).

undertaken. We expect there to be a significant difference between energy acquisition and energy expenditure based on broad habitat characteristics and differences. Habitat selection in different seasons is a subject of topic 8 - "decision functions", and already has a substantial data base for Vancouver Island (deer component of IWIFR and others). The topic of vegetation succession dynamics should be given higher priority than the other half of topic 8, "decision functions", which deals with forage selection decisions by deer.

Because this problem analysis has been generated simultaneous to field research, a body of data already exists which is relevant to several of the potential research topics. In particular, topic 1 is already in its first draft phase; topic 2 is ongoing at UBC; and adequate data have already been collected to evaluate topic 9 (Table 10). Topics 1,2, and 9 are exempted from the priority ranking since they have been funded and/or are nearing completion. In addition, preliminary data have been collected which support topics 4,7,8, and 10.

7.2 Research Framework

The IWIFR deer project must be integrated with all components of the IWIFR program. A proposed integration of research topics and priorities is provided in Table 13. Note that these topics only relate to the response of deer to habitat and habitat conditions. Not included are topics concerning the direct effects of intensive forest management on habitat *per se* and on the interrelations between wolves and deer. A general research framework is depicted in Figure 15. The effects of predation (by wolves and humans) on deer populations would be logically appended to Figure 15 if a broader research framework was to be envisaged.

8 RECOMMENDATIONS

8.1 The Need for an Adaptive Management Approach

The problem of black-tailed deer/intensive forest management has been a high priority research endeavour for 15 years. Many of the studies, have been descriptive in nature. Most initial attempts at research have a similar phase of baseline data collection. Certainly, the knowledge gained over the 15 years has generated a considerable understanding of the Vancouver Island deer resource (Section 5.2). With this understanding, a number of

TABLE 13. A recommended framework for studying the research topics outlined in Table 10

Research topic	Priority (1 - 8)	Timeframe (short/medium/long)	Proposed methodology	IWIFR group responsible (deer/habitat/LBC/MOE)
1. Habitat suitability model	1	short	concise, clear word[1] model of current management hypotheses	All
2. Thermal cover	1	medium	scientific research[1]	LBC
3. Security cover	7	long	problem analysis	Deer
4. Locomotion in snow	3	short	collation and analysis[1] of existing data	Deer/LBC
5. Juxtaposition of habitat types	6	long	modelling followed by adaptive management on watershed scale	All
6. Predator influence	8	long	problem analysis attempt manipulative scientific research	LBC/MOE
7. Site fidelity	5	medium	data review followed by adaptive management	Deer
8 Decision function	2	short	analysis of data collected[1] collation of other data sets followed by modelling	Deer/LBC
9. Distance of movement	1	short	analysis and write-up of data collected	Deer
10. Winter-spring energy acquisition and expenditure	4	medium	modelling	Deer/LBC
11. Simulation modelling	7	long	adaptive modelling[1]	Deer/LBC

[1] Projects that are currently in progress.

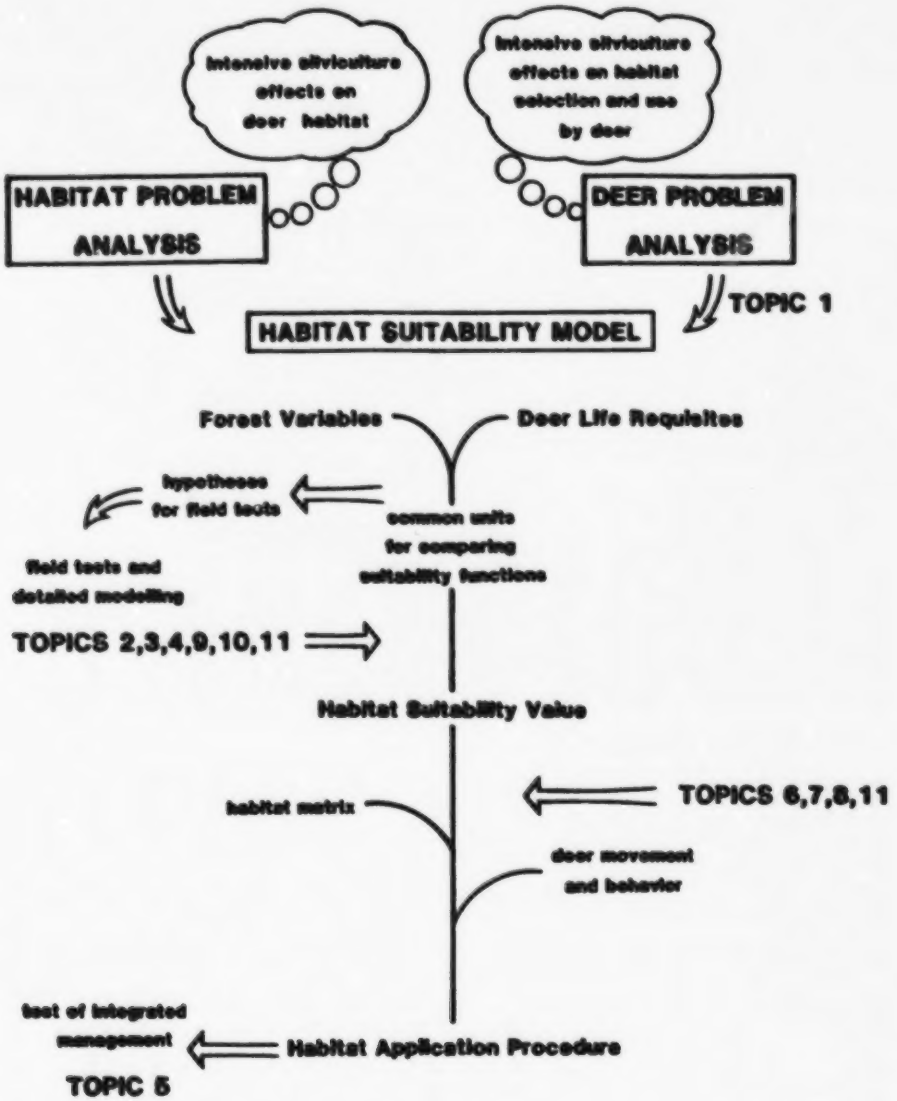

FIGURE 15. A general research framework recommended for the IWIFR deer project.

progressively detailed research topics has been developed (Section 7.2). However, as Macnab (1983) pointed out, little can be learned from natural systems by following their dynamics at equilibrium even if that equilibrium is upset by environmental perturbation. Manipulation needs to be included as a component of IWIFR research.

With the research of the past 15 years, managers now have adequate information to make management prescriptions. The important point is that these prescriptions for the most part not based on incomplete knowledge. The need for tests predominates. Testing management prescriptions on a small scale can provide confidence for managers and opportunities for experimental perturbation for researchers. The intent is to subject management hypotheses to the traditional scientific method (i.e., "adaptive management"; Holling (editor) 1978; Figure 16).

The role of research must be emphasized as a continual influx of "cause and effect" knowledge to the system. This process-level knowledge continually refines the management hypotheses. The paired, "control" and "manipulated or perturbed" comparison must be emphasized as well. Without controls, the perturbation experiment is often unbalanced and factors are confounded. Equally important is the necessity for monitoring results, which should be directed at measuring the control or unperturbed system, the source or active management implementation, and the effects on the manipulated system.

Changes to the current project implied by adoption of the adaptive management approach centre around reducing the effort spent on describing animals' use of habitat and to measuring changes in use, as well as other indices of deer response before and after system perturbation. Another change is the clear separation (but tight co-operation/communication) of management hypotheses testing and traditional research hypotheses testing.

Above all, manipulative and response variables should be clearly identified. Each particular research topic will have different variables associated with it but, nevertheless, the overall response variable should always be survival and productivity of deer. Deer response is expected to be difficult to assess and predict. Net energy is likely to be the best assessment method but is the farthest from field application and use. Condition indices are only now starting to become field applicable but still have inherent problems. Night counts and productivity counts are indices that allow assessment of carrying capacity and productivity directly in the

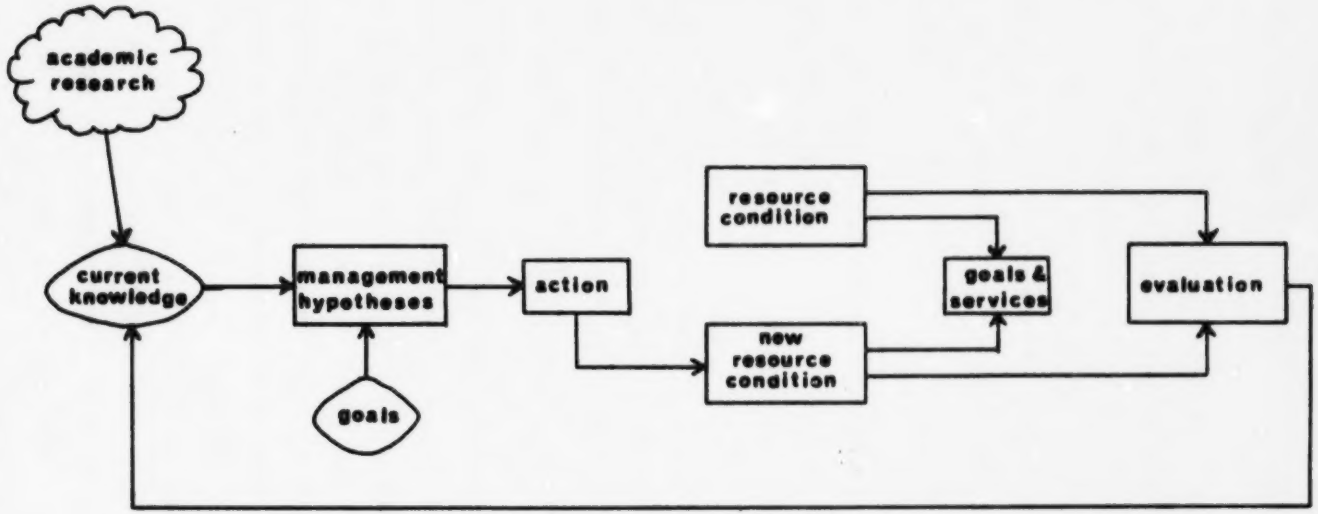

FIGURE 16. The adaptive management system.

field. Which method is chosen to assess deer response may vary according to the particular research topic.

8.2 Research Recommendations

The priority ranking scheme of Section 7.1 and the framework scheme of Section 7.2 lead to the following recommendations (topic numbers identify projects as listed in Table 13):

Short-Term Recommendations (1 year)

Topic 1 - A habitat suitability model should be prepared specifically to establish a basis for integrating management and to provide a simplified view of IWIFR research directions and research hypotheses. The model should be clear, concise and adaptable to new research findings.

Topic 9 - The activity and movement data that have been collected during the first phase of the IWIFR deer project should be collated, analyzed, and final reports written and submitted to scientific journals. Results will be mapped into Topics 10 and 4 below.

Topic 8 - The habitat selection data that has been collected during the first phase of the IWIFR deer project should be collated, analyzed, and final reports written and submitted to scientific journals. Results will be mapped into Topics 10 and 7 below.

Topic 4 - A detailed review and synthesis of locomotion costs for deer moving through snow should be prepared. The intent should be to link energy cost functions reported by Parker et al. (1984) to sinking depth of deer in coastal British Columbia. The results will be mapped into Topic 10 below.

Medium-Term Recommendations (2-3 years)

Topic 2 - The thermal studies ongoing at UBC should continue so that we gain an understanding of the relevance of thermal cover to deer.

Topic 10 - An attempt must be made to bring together winter-spring energy expenditures and energy acquisition functions and to show their connection with reproductive success and survival of deer. The attempt should be in the form of a modelling exercise based on the results of Topics 1,2,4,8, and 9 above, as well as data from other information sources such as Vancouver Island studies in Nimpkish, Sayward, Northwest Bay, and Cowichan Valley. The

results of this study will allow progression of Topic 1. Depending on the results, a field study may be necessary before confidence can be placed on the resulting model.

Topic 7 - An analysis should be made of data that provide information on site fidelity patterns in deer. Based on this analysis a field study should be proposed that would provide information concerning deer response to provision of "new habitat matrices". Results would be required for Topic 5.

Long-Term Recommendations (3-5 years)

Topic 5 - Tests should be made, at an operational scale, to determine how deer respond (behaviourally as well as reproductively) to large-scale changes in habitat juxtaposition imposed by integrated forest and wildlife management. The recommendation for this topic is made with the assumption that a satisfactory atmosphere for integrated management will be accomplished and that models of habitat and deer response to intensive forest management will be operational and relatively complete. Implementation of this topic as a field study could be used as a demonstration as well as a test of integrated forest and wildlife management.

Topic 3 - A short problem analysis should be prepared that details the problem of security cover for deer. Hypotheses would be mapped into Topics 5 and 11.

Topic 11 - A detailed mathematical model (in the fashion of UBC's STUF - see Section 6.2) should be prepared and updated as functional relationships are found and tested. This model would be more complex than Topic 1 and should be used to help structure verification tests of the habitat suitability model.

Topic 6 - A short problem analysis should be prepared that details the influence of predators on habitat selection and use by deer. Hypotheses would be mapped into Topics 5 and 11.

The reader is reminded that these topics are only general recommendations for research when animal- and habitat-related objectives are undertaken. Specific proposals for research should be prepared as required.

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APPENDIX 1. PERSONNEL CONTACTED

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Fish and Wildlife Branch, Nanaimo:

K. Brunt, Elk Project Biologist
D. Doyle, Deer Project Biologist
D. Hebert, Regional Wildlife Biologist (currently in Williams Lake)
D. Janz, Regional Wildlife Biologist
W. Kale, Wildlife Research (currently in Yukon Territories)
H. Langin, Wildlife Biologist (currently in Williams Lake)
B. Mason, Deer Project Technician
D. Morrison, Regional Habitat Protection Biologist
G. Smith, Wildlife Technician
M. Townshend, Habitat Protection Technician
J. Youds, Elk Project Biologist

Wildlife Branch, Victoria:

D. Eastman, Wildlife Research
P. Haley, Biometrician
I. Hatter, Ungulate Biologist
W. Macgregor, Ungulate Specialist
W. Munro, Birds and Endangered Species Specialist

Fish and Wildlife Branch, Kamloops:

D. Low, Wildlife Biologist
R. Ritcey, Regional Wildlife Biologist

B. C. Forest Service, Victoria:

R. Ellis, Research Branch
R. Page, Research Branch
K. Scouller, Contractor
S. Stevenson, Contractor
L. Stordeur, Research Branch
R. Thompson, Wildlife Biologist

B. C. Forest Service, Campbell River:

D. Sluggett, Operations Superintendent

B. C. Forest Service, Vancouver:

B. Nyberg, Research

B. C. Forest Service, Williams Lake:

H. Armleder, Mule Deer Project

Parks Branch, Victoria:

G. Jones, Wildlife Biologist

B. C. INDUSTRY

MacMillan Bloedel Limited:

B. Bourgeois, LUPAT Manager
J. Lavis, Forester
R. McLaughlin, Wildlife Biologist
G. Westarp, Forester

B. C. Forest Products:

S. Leigh-Spencer, Biologist

Pacific Forest Products:

V. Korelus, Forester

UNIVERSITY

University of British Columbia:

F. Bunnell, Professor
M. Gillingham, Doctoral Candidate
F. Messier, Doctoral Candidate
D. Seip, Post Doctoral Student

Simon Fraser University:

A. Harestad, Assistant Professor

University of Victoria:

T. Bergerud, Professor

ALASKAN GOVERNMENT

Alaska Fish and Wildlife and Forest Service:

T. Hanley, Forest Service

J. Schoen[1], Wildlife Biologist
([1] Indirect solicitation of problem analysis.)
O. Wallmo, deceased

PUBLIC INTEREST GROUPS

Nanaimo Fish and Game Protective Association:

Various members

APPENDIX 2. GLOSSARY

Animal condition: a measure of the physical health and fitness of an individual (Hatter 1982); used here to connote potential for survival and successful reproduction of viable offspring.

BMR: Basal Metabolic Rate (BMR) is the minimum rate of metabolism measured under resting conditions at a temperature where the animal is not required to expend energy for extra heat production or cooling (Krebs 1978).

Carrying capacity (K): ecological carrying capacity is the maximum population that a given environment can support indefinitely (Keeton 1972); an equilibrium resulting from all natural factors (Leopold 1933). Ecological K is interpreted here as being influenced by all ecological factors and is necessarily a dynamic equilibrium. More specific definitions are provided in Table 3 of Section 5.

Compensatory predation: the killing of prey animals by predators that would not survive and reproduce in the absence of predation (Hatter 1982).

Cutover: a logged area still in an initial seral stage (Hatter 1982).

Density dependence: an inverse relationship between rate of population growth and population density (Hatter 1982).

Density independence: an unpredictable relationship between rate of population growth and population density (Hatter 1982).

Ecosystem: biotic community and its abiotic environment (Krebs 1978).

Escape cover: those habitat features, vegetative or topographic, that allow a prey animal advantage in moving away from pursuit by predators (Hatter 1982).

Habitat: the range of environments in which a species occurs (Krebs 1978).

Hiding cover: those habitat features, vegetative or topographic, where an animal can rest from predators or hunters, in an unstressed condition (Hatter 1982).

Home range: that area traversed by an animal in its normal activities of food gathering, mating, and caring for young, over a specified period of time (Hatter 1982).

Immature forest: any stage before a tree, crop or stand is mature (Nyberg 1985).

Limiting factor: a combination of density dependent and density independent processes that limits population size, and if removed, results in population growth (Hatter 1982).

Mature forest: the stage at which a tree, crop, or stand best fulfills the main purpose for which it was maintained (Nyberg 1985).

Multiple use: management of the different surface resources in a combination that will meet the various needs or demands of society.

Old-growth forest: a natural forest, uninfluenced by human activity, and beyond the mature stage, typified by very large trees, an uneven age structure and high structural diversity both horizontally and vertically (Nyberg 1985).

Optimal foraging theory: the assumption that an animal will maximize its efficiency of food intake through its particular foraging behaviour.

Prey vulnerability: encompasses all physical and biological conditions that make one individual more likely to fall prey than another (Hatter 1982).

Proximate cause of mortality: the proximate cause of mortality refers to the immediate agent of mortality (e.g. predation), whereas ultimate causes refer to those factors, usually environmental, which are primarily responsible for deaths (e.g. food shortage, severe weather)(Hatter 1982).

Recreation-days: one recreation day is equivalent to one person recreating in the environment for all or part of one day.

Regulating factor: density dependent factors that can limit or expand (i.e. regulate) population growth.

Second-growth forest: forest growth that has come up naturally or artificially after some modification of the previous forest crop (e.g. wholesale cutting, fire or insect attack) (Hatter 1982).

Silvicultural treatments: forestry activities undertaken to enhance production of commercially valuable tree species, including thinning, silvicultural fertilization, highsite conversion, and commercial thinning (Hatter 1982).

Sustained yield: implies continuous production with the aim of achieving, at the earliest practicable time, an approximate balance between net growth and harvest, either by annual or somewhat longer periods.

Tree Farm Licence (TFL): Crown land leased to forest companies for the specific purpose of practising sustained yield forest management.

Winter range: area that animal uses during winter months, often characterized by south-facing slopes, low elevation, and particular forage resources or overstory cover types (Nyberg 1985).

Young-growth forest: forest stands or crops that have not yet reached the old-growth stage (Nyberg 1985).